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Metallurgical & Chemical Engineering

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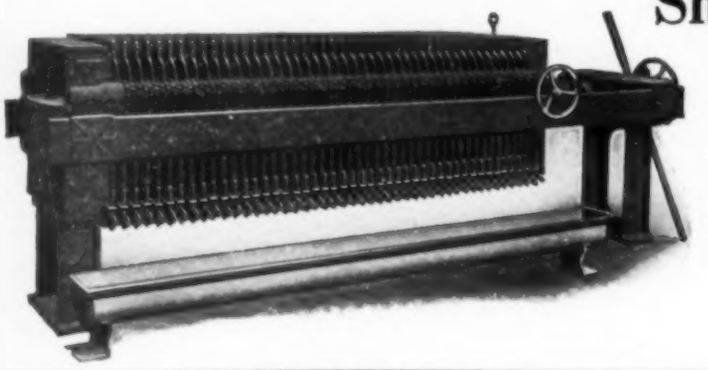

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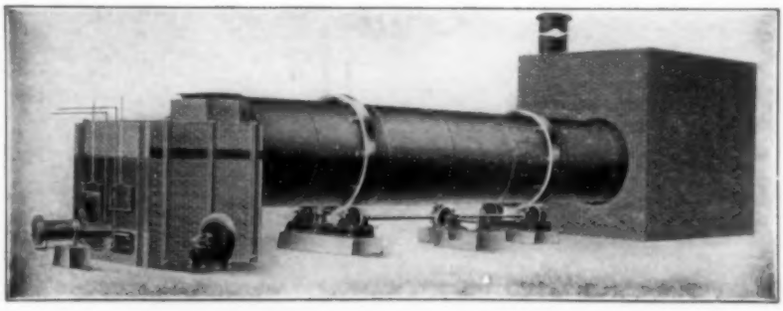

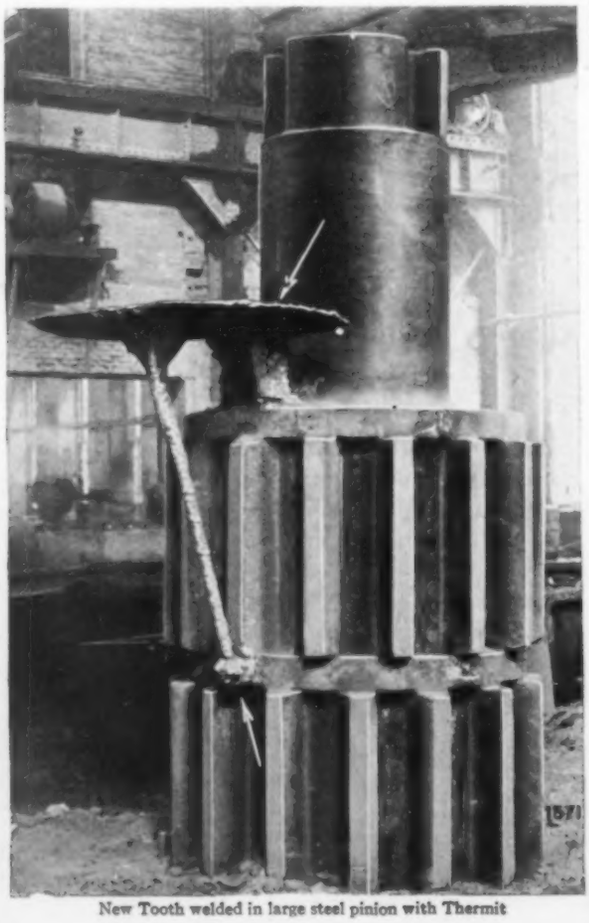

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Metallurgical and Chemical Engineering

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The Place Value of Waterpowers

In this issue we publish an interesting letter by "A. C." who asks whether we are not becoming unduly excited over Niagara power, and suggests the possibilities of cheap power from gas and the prospects of developing other waterpowers outside of Niagara. His are sensible questions. There is no doubt that in the directions indicated by him an enormous amount of hard and progressive work remains to be done. Think alone of the existing beehive coke ovens and what could be done with by-product coke ovens. Other waterpowers than Niagara in other parts of the country also have a serious right to be taken into consideration. As a single example, Muscle Shoals on the Tennessee River, if developed, might offer an excellent location for a cyanamid factory —with the Southern fertilizer market at its doors and protected by its inland location against foreign aggression if the factory should be turned over to making nitric acid for explosives in case of war. But this example also brings out clearly one point which is usually overlooked, that is the "place value" of a waterpower. As things are, most of the potential sources of cheap power which remain to be developed, will be linked to certain specific industries by considerations of raw materials supply and market.

Dr. Baekeland some ten years ago said that one chief factor determining whether a chemical process would work successfully, was Mr. Edward Harriman. Mr. Harriman is dead, but Dr. Baekeland's remark is as true to-day as it was ten years ago. That transportation costs play an enormously bigger part in the industrial life of this country than that of any other country, can be shown by a few indisputable comparative figures. As a basis we will use a few figures given by Mr. J. R. Finlay in his admirable paper on "industrial energy as a military weapon," published in our issue of Sept. 1, 1915 (Vol. XIII, p. 547). Mr. W. L. Saunders, in his speech last month before the New York section of the American Electrochemical Society (our issue of March 1, 1916, p. 259), based his convincing argument on a similar line of thought. Mr. Finlay considers as one chief criterion of a nation's industrial activity the consumption of fuel. This is 5 tons per capita for the United States, 4 tons per capita for England and Germany, 1.6 tons per capita for France, 0.25 ton per capita for Russia. These figures are a direct indication of the degree to which a nation has succeeded in multiplying the natural working productiveness of its average citizen by industrial development. Clearly the United States is easily the foremost industrial nation; the industrial output per man is greater in the United States than in any other country. Now let us change the viewpoint and instead of considering tons of fuel per capita

let us consider tons of fuel per square mile of area of the country. We leave it to our readers to calculate the figures. Without figuring at all, it is at once evident that the sequence of the figures for the different countries is entirely upset. What does this mean? Nothing more than that this country is very much less industrially populated than England or Germany and that the cost of transportation between the different industrial centers among each other and between industrial centers and sources of raw materials and markets respectively must be very much greater. In parenthesis it may be said that just this consideration explains why in the chemical industries certain things are possible in Germany which are impossible in this country.

If the economic value of a commodity is made up of place value, time value, and form value, and if place value is determined by transportation costs, it is thus clear that the place value is much more important in this country than abroad. This is necessarily true also for waterpowers. What has given Niagara its unique position among American waterpowers is its connection to the great lakes, with 3600 miles of shore line and navigable to the very docks at Niagara. The least expensive sort of transportation is thus provided for Niagara products to markets representing nearly half the population of North America, while the least expensive supply of raw materials is provided in many cases by the same water way, quite aside from the railroads running from Niagara in all directions.

This journal pledges its full support to any sensible waterpower development in any part of the country. But as things are at present, we must insist that, as a matter of fact, among American waterpowers Niagara Falls is in a class by itself. It is the place value of Niagara Falls which in conjunction with the available power makes it a national asset of unique economic value to the American nation. If the waste of power at Niagara is continued in future as heretofore, the only real loser is the whole American nation.

Value of Continuous Operation in Ore-Testing

Engineers experimenting with the flotation process are having their attention drawn to the value of continuous operation on a small scale in order to secure the most reliable data. It has been customary when making preliminary tests by the agitation-froth method, for example, to use a small single-cell machine and a few ounces of ore, keeping the pulp in closed circuit until no more froth is obtained. From such tests we get an approximate idea of the efficiency of oils, grade of products and general applicability of the process.

On the other hand there are certain factors which are not determined by such tests on a single-charge system. In practical application of the process various flow-sheets may be employed: A rough concentrate from several cells may be cleaned in another set; a middling product may be returned continuously and combined with the original feed; oily water may be recovered from concentrate or tailing, or both, for re-use; in short, commercial practice varies from the conditions of small tests by introducing factors that may have a cumulative effect not observable in an experiment with a single charge. The latter will not reveal the effect on the grade of concentrate caused by continuous return of middling, nor will it show the influence on oil consumption produced by use of recovered water. Therefore continuous testing on a small scale is advocated in order to observe the cumulative effect of certain factors and permit correct deductions.

To a certain extent the same principle applies to other metallurgical work. In cyaniding, for example, continuous operation shows the chemical effect of certain inconspicuous elements or compounds in the ore which may exert their full influence only after they have accumulated in solution. The same is true of smelting, where the recovery and retreatment of by-products acts as a concentration process for deleterious substances that are not in evidence in the beginning of operations. Copper and zinc leaching and electrolytic deposition are other examples of processes in which complete information cannot be obtained by intermittent or charge tests. It has long been recognized that so-called "full scale" tests are not essential for preliminary investigations, but the principle of continuity on a small scale seems to be sound in cases where it is at all practicable. Where it is not, refined chemical analysis of the ore will be of marked assistance in forecasting the necessary precautions and the probable results.

Need of Ball-Milling Data

The ball-mill is making a strong bid for popularity as a crushing machine, and some of its advocates enthusiastically see the beginning of the end of stamps, Chilean mills, Huntington mills and other competing types of crushing and grinding apparatus. Considering the comparatively recent advent of the modern type of ball-mill, its performance excites interest and admiration and lends color to the claims of its optimistic supporters. There is no doubt that the machine will grind ore in large quantities and effect a satisfactory reduction in size at one passage through the mill. Due to the rapidity with which the crushed ore is removed from the crushing zone and discharged from the mill, the product is granular and well adapted to gravity concentration or flotation.

Aside from figures on tonnage, screen analysis and power, however, data are meager; and such as are available have only local significance. Installations are comparatively new as well as few, and mills have not been in operation long enough to afford reliable data on cost and efficiency in comparison with other types of grinders. It would be instructive, for example, to compare in every essential detail the work of the modern ball-mill with that of the Chilean mill in the Cripple Creek district where the latter has shown a remarkable performance.

Time and experience will verify the correctness or falsity of the figures on mesh-tons crushed per unit of power and the cost for repairs on ball-mills, and afford some basis for comparison with other machines. Meanwhile there is an absence of data and exact knowledge

on the most economical load of balls and size of balls for a given size of mill, as well as the correct ratio of the different sizes of balls in the total load. Determination of these factors would indicate the correct procedure in adding new balls to the load, not only as to quantity but also as to ratio of sizes.

It would seem, for example, that there is a correct ratio of sizes that will fill the grinding zone to the best advantage, giving the proper percentage of voids and the proper number of points of contact for efficient grinding. Assuming a mill to have been started with ball sizes in correct ratio, it would seem to follow that future additions of balls should be of such sizes and quantities as to maintain the original ratio. In practice, however, it is not uncommon to replenish the supply by adding only the largest balls, on the assumption that they will be reduced in size and keep the ratio constant.

Is this assumption correct? If we fill a cylinder with balls of, say, three different sizes, it will be found that the number of each size that can be introduced increases with startling rapidity as the size decreases. Assuming this condition to represent the desired ratio of sizes for efficient grinding, it becomes apparent that the largest balls, which are least in number, cannot be depended upon to furnish the requisite supply of small balls which originally existed in much greater number. If this is true, then small as well as large balls should be supplied to keep the crushing load constant in weight and in ratio of ball sizes.

The whole subject of ball load is worth investigation for the purpose of securing definite data on the most efficient manner of operating ball-mills. The matter could well be investigated in the testing laboratories of our schools of mines, or by large operators, or even by the manufacturers.

The Pig Iron Production Statistics

Pig iron production in the United States in 1915 is officially reported at 29,916,213 gross tons, according well with the estimate of 29,900,000 tons made in our review at the beginning of this year. The year's output fell 3.4 per cent short of the output in the banner year 1913, 30,966,152 tons, but the output in the second half of 1915, 17,682,422 tons, broke the record for a half year, 16,488,602 tons, in the first half of 1913, by 7.3 per cent. The present indications are that 1916 will show an output close to if not quite 40,000,000 tons, which would break the calendar year record by 29 per cent.

The sharpness of the swing from Bessemer to basic open-hearth steel is shown by the fact that while the output of basic pig iron in 1915, 13,093,214 tons, broke the previous record, made in 1913, by 4.4 per cent, the Bessemer output, 10,523,306 tons, fell short of the production in seven of the preceding years, and was but a negligible amount in excess of the output in 1902. The present year will show as large an output of Bessemer iron as the existing Bessemer-steel-making equipment can consume, but as some of the equipment has passed to the scrap heap and some has been diverted to the duplex process it is a question whether the output will equal that in the banner year 1906, 13,840,518 tons.

The large steel works and even the moderate sized works, are practically self-contained as to pig iron. The tonnages made for sale, chiefly by regular merchant furnaces, as only a few steel interests, exceptionally placed, sell any pig iron, was as follows in 1915, with the proportion the merchant iron constituted of the total output:

	Gross Tons	Per Cent
Basic	1,747,265	13.3
Bessemer and low-phosphorus	871,730	8.3
Foundry	4,801,711	98.7
Malleable	829,921	100.0
Forge	174,355	52.2
All other	158,025	54.6
Total	8,583,007	28.7

The tonnage designated above as "all other" included spiegeleisen, ferromanganese, direct castings, etc. While the merchant production was 54.6 per cent of the total there is little doubt that more than one-half the spiegeleisen and ferromanganese was made by steel interests.

The production of ferromanganese in the year was 129,072 tons, breaking the previous record of 125,378 tons, made in 1912, by a small margin, but the production in the second half alone, 83,628 tons, was undoubtedly far in excess of the tonnage made in any preceding half year, and represented fully 70 per cent of the maximum requirements hitherto experienced, in 1912 and 1913. While the production of steel is much larger, the means employed at many works for getting along with smaller proportions of ferromanganese are probably sufficient to reduce materially the total consumption of ferromanganese in proportion to the steel output. The use of spiegeleisen and ferrosilicon, for instance, has been greatly increased.

The statistics of the tonnage of iron delivered molten shows that there is very large employment of the direct metal process. Of the total output of Bessemer and low-phosphorus pig iron the tonnage delivered molten was 70.7 per cent. Making allowance for a relatively small tonnage of Bessemer that is delivered molten by merchant furnaces to ingot mold foundries, and deducting an estimate for the low-phosphorus output, it would appear that the steel interests used about 78 per cent of their Bessemer pig iron output as direct metal. The remaining 22 per cent of iron that was cast was not all "Sunday metal" by any means, as commercial conditions were such in the early months of the year that a considerable tonnage was doubtless cast for stock, to be carried weeks or months. A year like the present will probably show a much higher proportion than 78 per cent.

Of the total production of basic iron in 1915 73.8 per cent was delivered molten, the highest proportion yet shown. Substantially all the merchant basic iron was undoubtedly cast, so that the 9,648,769 tons delivered molten may be compared with the 11,345,949 tons produced by steel interests, showing a proportion of 85 per cent direct metal, and leaving room for the introduction of very little additional refinement in making the blast furnace and open-hearth furnace work hand in hand.

Reader's Views and Comments

Power from Niagara Falls and from Other Sources

To the Editor of Metallurgical & Chemical Engineering

SIR:—Are we not becoming unduly excited over Niagara power? Can we not have a discussion on the cost of power from various sources?

For example, natural gas sells for 5 cents per 1000 cu. ft., *or less,* in some sections of the West Virginia field. With the most efficient type of gas engine it would seem as though power from this source might work out as cheap as Niagara power. And salt is at hand.

And with the Mond producer-gas process gas seems almost a by-product—without cost—of a chemical plant producing a very high yield of ammonia, together with the usual tar products, and coke. Locate such a plant on a culm bank at the mine, convenient to salt, and low costs should result.

And then what is the matter with other water powers? Is not the Mississippi Power Co. at Keokuk, Iowa, looking for business? What about Massena, N. Y.? There are doubtless many locations in our own state (the upper Hudson, for example) and in New England where developed and undeveloped large and small powers are available.

Finally, it ought to be possible to buy current of some of the great central-station companies in our larger cities. Prices approximating ½ cent per kw-hour—for certain uses—have been rumored. Of course, any such rate would only apply to those hours of the day when the regular lighting and power load is unusually light. Here regular service takes care of "overhead charges," so that anything in excess of coal costs, plus additional labor, wear and tear and supplies, should be profitable.

What does Niagara power cost the consumer?

A. C.

Brooklyn, N. Y.

Congress and the Dyestuff Situation

To the Editor of Metallurgical & Chemical Engineering

SIR:—The Right Honorable, the LXIV Congress is now in session. It assembled on Dec. 6, 1915, and adjourned for the holidays on Dec. 17. During that period 6848 bills were introduced of which 4144 (which sounds almost like four-'leven-forty-four) were pension bills of which practically every one had been already presented to the pension office and rejected. One honorable member is the happy father of 208 of these bills. There were also introduced 198 bills changing military records, which are increases in pensions, and 1037 bills for claims which the United States Court of Claims had not regarded as sufficiently justified to approve. There were 718 local bills in which the people of the United States had no interest whatever as, for instance, one (H. R. 409) "authorizing the Secretary of War to donate to the City of Elsberry in the County of Lincoln, Mo., two bronze cannon or field pieces, with their carriages." It requires the deliberations of the 434 members of Congress at $7,500 per year plus mileage to determine the future of Elsberry's hitching post! Of the 758 additional measures proposed and called for politeness' sake public bills, over one-half of them were, in point of fact, of private rather than public interest. I have these details from the bulletin of the National Voters' League.

Now the only possible good to come from these enactments is Votes for Congressmen. The Pension Department and the Court of Claims are discredited and their work made of no avail; the lavish waste of money is like nothing more sober than a drunken sailor, and if it were not for the inestimable boon of having the present incumbents remain in the place of others who might be elected to succeed them in Congress after the next election, it would almost seem as though the money were spent for nothing.

These things give us something of a jolt. And yet, these gentlemen are the real representatives of the people; they are the means whereby democracy is justified—or fails. Congress is *us,* and if we do not like it let us at all events quit boasting and stop complaining. Neither will do any good. It all comes back to abuse of ourselves, for these are our representatives and we have elected them. Our Congressmen are our contribution to Democracy. The Civil Service men have nothing to do with what the gifted orator calls the In-stye-tootion o' Liberty; neither have department chiefs nor cabinet ministers. Congress is the people; and there's many a conscientious, able and earnest man in that body.

Then what's the matter with it?

Despite all that I have said there isn't anything in particular the matter with Congress. The matter is with us, us citizens. We haven't kept watch; haven't paid attention to what Congress did. It has not been interesting and so we have let the whole thing go by the board and we have satisfied our consciences by kicking at the politicians. Of course, some manufacturers have taken an interest in Congress, a very selfish interest that hasn't done Congress any good, but we do not refer to the lobby when we refer to patriotic interest. We have just let things slip along until bad practices have crept in. Then they have become general; like the bribery of dyers. We do not pay any attention to Congress until something important like war or a question of honor, or a general welfare or a tariff bill comes around; and then we expect Congress to act. Now Congress with the best intentions does not know what we want—unless we are manufacturers, and then Congress is likely to learn that we want more protection than a mud-turtle-porcupine hybred. Otherwise we do not tell Congress anything. Congress knows (by experience, probably), that if we had a civil war record we should probably have put in appearance already, and if we do not want a position or some privilege or advantage, then we have no business with Congress. And Mr. Congressman addresses himself to the only people who seem to have business with Congress, to wit: those who want money and those who want favors. No wonder there are so many special bills; those are the very bills that count—to the Congressman. "Take all this yawp and hullabaloo about the dyestuff situation," he is likely to say. "People are making just the same kind of a noise that they always do whenever there is a tariff discussion." Mr. Congressman has heard that noise before and he wants to know why it means any more than it usually does? And if there isn't a single textile mill of any importance in his district, which is usually the case, what's the use, Mr. Congressman wants to know, of making such a fuss about it? Where does he come in? You see, half the Congressmen, irrespective of party, are built this way and think this way. Experience in public life has taught them what the public wants, which is pensions and favors. Then, if a man keeps regular with his party and looks after the boys in

his district pretty well, his political future is fairly well assured—until the next landslide. So it is a pretty good plan to introduce bills for everything that can help a man, politically, in his district and then use them for trading purposes later.

What is the refrain that we constantly hear before elections at political meetings—provided we go and listen? Almost invariably it is "Vote for Hon. John R. Gobblevote for Congress. He looks after the people of This District." There are the two bronze cannon and their carriages, put there by special Ack o' Congress, and the village drunkard with his pension and the dashing young widow with hers and appropriations for this and that and t'other. That's what counts!

So if a chemical schedule goes through, even though it be approved by the wisest and soundest and best informed of commissions and committees, we may be sure that it will carry with it a million or so a year in pension bills that have heretofore been rejected.

Bills for disallowed claims and rejected pensions are the yellow trading stamps of The People. By them our rights are conserved and good government is purchased.

X. Y.

A Nomographic Blast-Pressure Chart

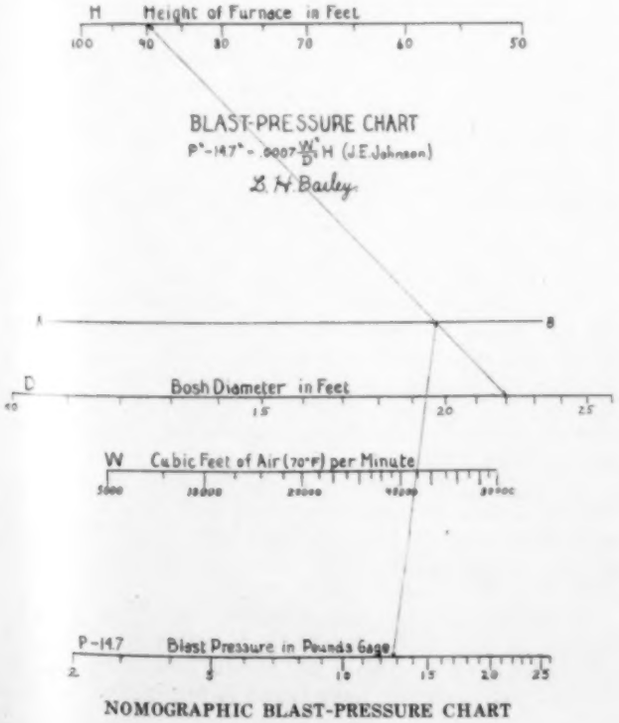
To the Editor of Metallurgical & Chemical Engineering

SIR:—In looking over your Jan. 1, 1916 number, I was greatly interested in the remarkable contrast between Mr. Haylett's charts on page 9 and the one on page 44 in connection with Mr. Johnson's excellent article on the blast-furnace. The construction of the accompanying chart is a matter of an hour or a little more and gives the same results as the rectangular chart in about one-third of the "one minute" claimed by Mr. Johnson.

Mr. Johnson's formula,

$$P^2 - 14.7^2 = .0007 \frac{W^2}{D^4} Hi,$$

by the use of nomographic methods, can be represented by four graduated scales for the four variables and one supporting line AB. The application of this chart to the solution of problems is extremely simple.



NOMOGRAPHIC BLAST-PRESSURE CHART

Example: Height, 90 ft., bosh diameter 22 ft., blast 45,000 cubic feet. What pressure is required?

Solution: Connect 90 ft. on the H scale with 22 ft. on the D scale. From the point of intersection of this line with line AB draw a line through 45,000 on the W scale. This line will cut the P scale in the required value, 13.7 lb. gage.

As will readily be seen it is just as simple to solve for the volume of air, when the gage pressure and furnace dimensions are given.

I think Mr. Johnson will agree that of the two charts, the nomographic chart is much simpler to construct and much less confusing to use.

LAWRENCE H. BAILEY.

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Boston, Mass.

Classifying

To the Editor of Metallurgical & Chemical Engineering

SIR:—I have read with interest Mr. E. S. Wiard's valuable article in your issue of Jan. 15, on "The Grading Industries."

The discussion of the type of grading which he states is incorrectly called "classifying" is of necessity limited, in such a comprehensive paper; and I would like to add to it some further data on the work of the machine with which I am identified.

The word "classifier" to describe a device for separating a stream of pulp into only two products came into use in cyanide metallurgy when leaching sand was practised and more attention was paid to sand and slime separation, and when cones with an upward or washing current were adopted instead of the collecting tanks or spitzkasten. When in 1904, after a troublesome experience with the so-called "cone classifiers," the idea of accomplishing the same separation by removing mechanically the sand from a settling vessel occurred to me, it was natural to call the resulting machine a "classifier," especially as I did not realize then that mechanical devices had been frequently used in concentrating mills for sand dewatering. The wide adoption of my own and later developed types of mechanical "classifiers" in cyaniding, and their value in fine grinding in closed circuit for the "all-slime" treatment, brought them to the attention of concentrating men. The scope of their work has been increased from the original separation of leachable sand, (often a large per cent under 200 mesh) and colloids, to making a —200 mesh or —150 mesh so-called "all-slime product," and finally to making a separation at 48 and 60 mesh, such as is being done with our machines at the Inspiration and Anaconda in preparing a flotation product.

Surely such machines should no longer be called "dewaterers" or "deslimers," as many of my concentrating friends have insisted.

We all realize the difficulty of obtaining reliable data on the performance of different types of machines, and know how easy it is to get incorrect impressions due to the incomplete data that get into circulation. The comparative tables given by Mr. Wiard illustrate this very well. He states: "Table 1 illustrates the *capacity* and work of the three classifiers. The figures in the case of the Dorr and the Akins are comparative, having been made in the same mill on the same material." (The italics are mine.)

As the feed given showed only 76 tons going to the Dorr with an overflow of 19.4 per cent plus 200 mesh and 92.7 tons to the Akins with an overflow of 22 per cent plus 200 mesh (practically the same), the only inference to be drawn would be that the former had less capacity at that point of separation.

On reading his paper I recognized the screen tests

at sight and felt that as they had been published, further information was warranted in the interest of entire accuracy. Nearly five years ago, the same screen tests were brought to me as having come from the superintendent of a well known mill and as being used by others to prove that the Dorr machine had the smaller capacity. Realizing that capacity is largely a matter of settling area, and knowing that the Dorr machines were handling much greater tonnages elsewhere, I called on the superintendent, who assurred me that in sending out the tests to inquirers he had not intended to imply that the data represented what he considered the comparative capacity of the machines, but only the feed when the tests happened to be made.

He regretted that any incorrect inferences had been drawn, and very kindly offered to make further tests. These were made under his supervision and the results sent us by him, as shown in Table I.

TABLE I. CLASSIFIER TESTS BY —— COMPANY

Received from —— July, 1911.
Dilution of feed about 4½ :1.

	Feed Dorr about 145 tons per 24 hours. Feed Akins about 145 tons per 24 hours. July 12, 1911		Feed Dorr about 145 tons per 24 hours. Feed Akins about 75 tons per 24 hours. July 6, 1911		
Heads	Dorr	Akins			
+40	12.8%	9.4%			
+60	16.8	20.3			
+100	9.3	11.6			
+200	13.4	11.6			
—200	47.1	47.8			
Slimes			Slimes	Dorr	Akins
+100	0.2%	14.3%	+100	0.9%	2.9%
+200	8.7	17.5	+200	5.8	11.2
—200	91.2	68.0	—200	94.7	85.9
Sands			Sands		
+40	34.7%	36.4%	+40	33.1%	26.7%
+60	29.1	42.1	+60	29.7	34.1
+100	14.2	9.9	+100	12.5	15.3
+200	13.5	7.4	+200	16.2	16.8
—200	7.9	3.3	—200	7.4	6.9

Daily tests on Dorr loaded at 145 tons per 24 hours

Slimes	1	2	3	4
+100	0.2%	0.7%	1.6%	1.7%
+200	6.4	9.4	5.4	9.7
—200	93.4	89.9	92.9	90.3
Sands				
+40	26.5%	28.0%	25.8%	36.9%
+60	29.1	30.0	30.5	30.6
+100	13.2	17.6	16.4	13.8
+200	18.5	14.8	17.6	12.8
—200	12.0	9.6	8.5	6.1

These figures are much closer to those obtained with Dorr classifiers under similar conditions elsewhere, and taken together certainly can be considered more informative than the single one previously given.

On discussing the matter with Mr. Wiard, he advised me that he had received the figures he had published some years ago, and was glad to have me publish the others as well.

The figures of Table II from other plants may be of interest as showing the capacity of the classifier under varying conditions.

TABLE II. SCREEN TESTS

Standard Duplex Classifier, not in closed circuit. Feed 155 tons per day from stamp battery. Screen test of feed not given.

Mesh	Sands	Overflow
+10	15.0%	...
+20	16.8	...
+60	40.0	0
+100	14.0	0.2%
+150	4.2	1.0
+200	4.6	2.8
—200	4.9	96.0

Standard Duplex Classifier in closed circuit with a tube mill.
Original feed to classifier..... 55 tons
Classifier sands or tube mill return.....125 tons
Total feed to classifier.....180 tons

Mesh	Sands	Overflow
+20	3.0	...
+40	5.5	...
+60	7.5	...
+100	37.0	0
+150	...	3.0%
+200	41.0	7.0
—200	16.0	90.0

Standard Duplex Classifier in closed circuit with tube mill. Chilean mill used for preliminary grinding.
Original feed or discharge of Chilean mill.....133 tons
Sand return from classifier or tube mill feed..... 93 tons
Total feed to classifier.....226 tons

Mesh	Chilean Mill Discharge	Tube Mill Discharge	Classifier Sands	Classifier Overflow
+20	9.7%	...	...	...
+40	16.2	...	...	...
+60	14.7	...	...	...
+100	12.8	8.7%	83.6%	4.9%
+150	9.4	10.5	7.0	8.7
+200	6.0	11.4	3.0	10.3
—200	31.2	69.4	6.4	76.1

Standard Duplex Classifier in closed circuit with a tube mill.
Original feed to classifier.....150 tons
Sand return from classifier or tube mill feed.....190 tons
Total feed to classifier.....340 tons

Mesh	Total Feed	Sands	Overflow
+20	28.9%	26.5%	0
+60	21.2	35.2	0.8%
+100	12.0	14.8	1.0
+150	9.1	7.0	6.4
+200	4.0	4.0	12.6
—200	24.8	12.5	79.3

Material: Roasted ore.
Tonnage: 300-350 tons per day.
Dilution of feed: 3.5 to 1.

Mesh	Feed	Slime Overflow	Sand
+30	7%	..	10%
+40	10	..	14
+60	20	..	30
+80	5	..	7
+100	10	..	15
+150	5	2%	7
+200	7	4	10
—200	36	94	7

Duplex Extra-heavy Classifier 6 ft. in width in closed circuit with ball mill for coarse separation. Dilution overflow 3 to 1.
Original feed to classifier..... 361 tons
Classifier sands or ball mill return..... 855 tons
Total feed to classifier.....1,216 tons

Mesh	Feed	Sands	Overflow
+6	0.3%	1.6%	...
+8	1.0	3.0	...
+14	5.6	12.6	...
+28	17.0	25.0	...
+48	26.2	33.4	0.7%
+65	11.0	11.4	3.6
+100	7.1	4.4	7.8
+200	7.0	3.2	14.8
—200	24.8	5.4	73.1

Power.—Mr. Wiard states the power required for driving any of the machines mentioned (Dorr, Akins, Esperanza) does not exceed 0.01 to 0.02 horsepower per ton of solids handled per day. This is certainly conservative as far as the Dorr classifier is concerned. It has usually been difficult to get measurements of power taken, as it is so trivial. The Desert Mill, however, reported a measured consumption of 0.66 horsepower (motor input) for 580 tons solids per day, which with normal motor efficiency will not exceed 1/10 of his low figure, and other data has indicated approximately ⅛ horsepower per 100 tons solids in feed.

Maintenance.—Without wishing to bore your readers with a discussion of points that may be considered largely matters of opinion, I desire to touch on several other conclusions reached by Mr. Wiard. He considers that for general attention and lubrication the Dorr will be the worst of the three machines discussed. This conclusion as compared with the Akins might readily be reached by one who has not operated the Dorr and has had his attention called to its numerous parts, but would not seem tenable against the submerged joints of the Esperanza.

A study of the details of construction of the Dorr will show that all parts moving on each other are raised well above contact with the pulp and, except the crank, all joints are in continuous tension so that if wear occurred no lost motion would result.

In actual practice, the attention for oiling, etc., required by any of the machines is extremely light, and with the careful system of grease lubrication on the Dorr, most operators have found it negligible.

As to wear and tear of rakes or moving means, Mr. Wiard considers the Akins will report the most, and thinks there will not be much to choose between the Dorr and the Esperanza. Theoretically, I should put the Esperanza far ahead of the other two on this point, one reason being that it has wear not only on the moving parts, but on the bottom as well, while the Dorr and Akins form a bottom of packed sand. I have very little data on this, but know that at one well-known plant in Ontario, grinding a very hard ore very fine, an Esperanza was installed after six Dorrs had been running a year or more, and the superintendent advised me that he had been obliged to put in entirely new moving parts in the Esperanza, while the Dorrs had had no repairs. He subsequently added two more Dorrs to the plant, and wrote me: "I shall be very glad to give our experience with a drag classifier as compared with a Dorr classifier, as we have the drag classifiers working under exactly the same conditions as one of your long Dorr classifiers. The results of this experience are very much in favor of the Dorr type of classifier, both in regards to work done and repair costs."

While the belt and scraper type, which is undoubtedly very old, and was described by Scobey in 1904 as being used for tails dewatering, is not strictly an Esperanza, it is very similar and costs might be assumed to be analogous.

I had occasion a year ago to go into maintenance costs and obtained from one of the large well-known copper mills in Arizona the following:

DRAG MAINTENANCE

Total tons.....638,454 in 12 14-in. drags

Labor (upkeep).....	$827.74	
Sundry supplies.....	589.69	(Includes bottom liners)
Shop charges.....	241.82	(Chiefly transmission)
Belting.....	259.88	(Belts last about 2 years; cost about $70 each)
Scrapers.....	145.50	
Total.....	$2,064.63 = 0.3c. per ton.	
Maintenance per month per drag.....	$28.70	

As compared with this we have a cost of 0.1 per ton on the oldest type of Dorr machine, the manufacture of which was discontinued eight years ago, but which is still in use at the Golden Cycle mill.

One of the largest Nevada mills has reported a repair supply cost of 0.03 cents per ton of original feed, which means approximately one-half that per ton of total feed.

Another mill reporting two and one-half years' operation gives a maintenance of 0.024c. per ton, while one the writer was associated with showed only one roller replaced in three years, and several rakes reriveted.

The vital point that many people overlook is that these low repair figures mean much more in smooth operation of the plant than in actual savings.

It has been an interesting fact that on a fine feed 10-mesh and finer, the wear on the bottom of the scrapers was extremely small, as the following from the manager of a large Utah mill indicates: "I think the rakes on our Dorr classifier were in use fully five years and they showed no perceptible wear when we shut down. Very little sand went into the classifier coarser than 10 mesh."

With the ¼-mesh material now often fed the machines it has been very definite, although not enough to raise the maintenance figures.

Mr. Wiard states: "The Akins may often be started without digging out, while with the other two kinds this operation will be necessary."

If the settling box in any mechanical classifier is filled with hard packed sand, starting without loosening it will be very difficult. Users of the Dorr classifier advise us that under normal loads the machine starts with no trouble, but when heavily loaded or a large amount of sand is run in after a sudden shut-down, it is necessary to raise the rakes before the sand becomes packed. The machine can then be started and the rakes gradually lowered to the normal position.

Mr. Wiard comments on the products from the three classifiers and states the Akins gives the cleanest sand, the Esperanza the cleanest slime, and the Dorr the poorest. This appears to me a generalization without actual comparative data which it is difficult to get. It is naturally too large a subject for thorough discussion at this time, but what information I have been able to get from comparative tests shows that with an equal amount of sand thrown into the slime, the Dorr classifier, with its varied means of regulation and sprays for washing the sand before its discharge, will give at least as clean sand as any other machine I know. As to the Esperanza making a cleaner slime, there is no theoretical reason to assume this, and the work at Nipissing, when product entirely passing 200 mesh was wanted, showed the reverse.

JOHN V. N. DORR.

New York City.

Probability and Chance in Screening

To the Editor of Metallurgical & Chemical Engineering

SIR:—On page 194 of the issue of Feb. 15 Mr. Edward S. Wiard has allowed a mathematical error to creep into his discussion of "Probability and Chance in Screening." The statement is as follows:

"A little reflection will show that the chances of a grain falling through the square (opening) are the ratio of the area of the inner square to the area between the inner square and the outer, or

$$\frac{l^2 - 2l^2/n + l^2/n^2}{2l^2/n - l^2/n^2}$$

which reduces to $\frac{n^2}{2n-1} - 1$. (In the original there were two typographical errors, which I have corrected.) The inverse ratio fixes the chance of a grain *not* passing through, and is also a measure of the number of squares a grain will have to pass over before falling through."

Let us assume the correctness of Mr. Wiard's argument as to the size of the inner square under the conditions of the problem stated by him. If a number of grains of certain size strike the larger square indiscriminately, and can fall through only if they fall within the area of the smaller inner square, the chance for any particular grain to fall through is given by the ratio of the area of the inner, or *effective*, area to the *entire* area under consideration. Stated mathematically, using the same symbols used in the original article, the formula is $\frac{(l-l/n)^2}{l^2}$, which equals $(1-1/n)^2$. It will be seen that the formula is independent of the absolute size of the opening, depending only on the ratio of the grain size to the opening. The value of the probability of a particle falling through ranges from 0 when $n = 1$, or the grain is as large as the opening, to 1, or certainly, when $n =$ infinity, as with an infinitely small particle inner and outer squares coincide; in other words, the entire area becomes effective. The probability can never exceed 1.

The chance for a grain not falling through is not the reciprocal of the probability of its falling through, as stated by Mr. Wiard, but is equal to unity minus the probability of falling through. There are two alternatives; falling through and not falling through, and as the grain under consideration must follow one of these courses, the sum of the two chances must be 1 or cer-

tainty. This value of the chance of not falling through also represents the proportion of grains remaining in the oversize after passing over one square. After passing over two, the remainder will be the square of this value, and after passing p squares it will be the original remainder raised to the power p. This shows that by increasing the number of openings passed over, the screening can be brought nearer perfection, but 100 per cent efficiency can only be reached with an infinite number of holes, although it can be very closely approximated.

The following table gives the values of the probability of falling through, of not falling through, and the amount of the remainder on the screen after passing over various numbers of openings:

Value of n	Probability of—Passing Through	Probability of—Not Passing Through	Remaining in the Oversize After Passing Openings: 1	2	4	8	16
1	0.000	1.000	1.000	1.000	1.000	1.000	1.000
2	0.250	0.750	0.750	0.563	0.316	0.100	0.010
4	0.5625	0.4375	0.438	0.191	0.037	0.013	0.0002
8	0.766	0.234	0.234	0.055	0.003	0.000	....
16	0.879	0.121	0.121	0.015	0.0002	....	....

There is no expression possible for the number of openings required for perfect screening, as perfection is the limit that can never be reached under the assumed conditions. The expression for the remainder as given in the above table is

$$\left(\frac{2n-1}{n^2}\right)^p = R = 1 - E,$$

where R is the amount remaining in the oversize after passing p openings, and E is the efficiency of the screening operation. From this, $E = 1 - \left(\frac{2n-1}{n^2}\right)^p$, and

$$p = \frac{\log (1-E)}{\log \frac{2n-1}{n^2}}.$$

On page 195 Mr. Wiard apparently recognizes the correct statement of the probability of a grain falling through, as under the heading 'Interpreting the Chance Law" he states:

"Let x be the area of the chance inner square for any particular sized grain, and y the area between the inner and bounding square of the aperture. Then of A grains approaching a line of apertures of the lower limit of size, the fraction $x/(x+y)$ will pass through the screen and the fraction $y/(x+y)$ will remain in the oversize."

NATHANIEL HERZ.

Lead, South Dakota.

Perfect Heat Insulation

To the Editor of Metallurgical & Chemical Engineering

SIR:—In your issue of Feb. 15, page 227, second column, top, Mr. Boeck has referred to a paper of mine which was published in your issue of February, 1912, but by what is apparently an error in transcribing I am represented as having said something which in fact would be foolish.

The word "furnace" should have been "electrode." Perfect insulation in a furnace wall which is exposed on the outside is an impossibility. The perfect insulation which I referred to in the article to which he refers is that which could be maintained between a conducting electrode which passes through the walls of a furnace, and the wall immediately surrounding it, in which case no heat would flow from the electrode to the walls or the reverse.

This may be accomplished, as I think will be acknowledged by everyone, by having the heat gradient in that portion of the wall which is next to the electrode, exactly the same as the heat gradient in the electrode itself; the evident principle being that if there is no difference of temperature between two adjacent parts, there will be no flow of heat from one to the other. This is a *method* of insulating and not strictly speaking an *insulator*.

This, together with one other case, is the only possible way that I know of for producing perfect heat insulation; but the principle is evidently not applicable to making furnace walls insulate perfectly, which he reports me as having said, except if the outside of the furnace wall be heated to the same temperature as the inside, which would defeat the purpose of the wall.

In this connection, however, I may add that at the time of these discussions I pointed out that in a way the latter result might be approached at least for electric furnaces by heating the outside of the furnace as hot as convenient by means of a cheaper heat than electric heat; that is by placing an electric furnace, including its walls, inside of a gas heated furnace. Some time thereafter I noticed that a patent was taken out by some one else for this method of improving the heat insulation of electric furnaces.

CARL HERING.

Philadelphia, Pa.

Non-Ferrous Metal Market

Saturday, March 11.—The features of the market during the past two weeks have been the dullness in spelter and its consequent decline of about 3 cents per lb., and the British Government regulation to stop speculating in all metals entering into ammunition manufacture. This regulation which prevented sale of all metals except tin on the London Exchange went into effect on March 2, and had a depressing effect on our market. It was withdrawn on March 6, however, when trading in London was resumed.

Copper.—The copper market has been dull but has not developed any inherent weakness although spot prices are a trifle lower. Electrolytic and Lake are quoted at 27¼c. Exports for February were 20,548 tons. The strikers at the American Brass Company started to return to work on Feb. 28, with a 15 per cent increase.

Tin.—Spot tin has been very scarce and is now almost unobtainable. The future market is very strong. On Feb. 28 the price had risen to 50 cents but dropped to 46 cents on March 2, partly on account of the British regulation stopping trading in London. It has since risen again and is now quoted at 56 cents. Deliveries aggregating 6388 tons were made in February, which is a record.

Lead.—Lead is very strong and has been in good demand. The Trust raised the price to 6.40, New York, on March 3, and to 6.60 on March 7, which is now the quoted price.

Spelter.—Spelter, which was quoted at 20.50 two weeks ago, is now selling spot at 17.75. This decline was the result of dullness in the market. If there has been much business done in the last two weeks it is not generally known.

Other Metals.—Virgin **aluminium** is very scarce and is quoted at 62 cents. **Antimony** is likewise hard to obtain and has remained steady at 44.50. **Silver** varied about one-fourth cent and is now quoted at 56¾. **Platinum** remains nominal at $88 per oz. **Quicksilver** is quoted at $260 per flask.

The Iron and Steel Market

The steel market continues to show a sharply advancing tendency, though it is possible that the general average has not moved up altogether as much in the past fortnight as would be indicated by the pace in

February. On the last day of that month new discount lists were issued by the pipe mills, advancing black iron and steel pipe one point or about $2 a ton and galvanized two points, while boiler tubes were advanced one point. On March 1 came the expected advance of $2 a ton in wire products. Skelp has gone up about $4 a ton, in sympathy with the advances in pipe on Feb. 15 and Feb. 29, as well as the advance in plates of $5 a ton just after the middle of February. There have been sharp advances in various descriptions of manufactured steel, including shafting, rivets, etc.

The laws of steel market movements have been complex and confusing enough in the past, yet when one attempts to analyze the present situation he sees by comparison that the movements of the past were more or less regular. What is particularly startling at the present time is that there are no influences exerting any control. That may appear to be a rash statement, yet it can be supported by considerable argument. While our reasoning may not be altogether precise, we submit it is fairly accurate in substance, that normally the two great controlling elements are the physical and the psychological. The physical determines how much steel will be put into consumption, the question whether the consumption or the application of a given piece of steel will "pay," being really a physical problem, while the quantity that can be produced is usually considered a physical problem. The mill manager and the workmen are expected to do their best at all times.

What we have called the psychological controlling influence is of course the mental attitude of the two parties to a market transaction, the seller and the buyer.

Now as to the physical, it is to be observed that the steel being shipped at this time from the mills and passing, one may presume, into use, is not being paid for at present market prices. Orders are being filled on contracts that were placed more than six months ago. Even disregarding the fancy prices now being asked, and paid as to a limited tonnage, for prompt shipment, and taking as basis the prices asked by large mills for delivery far in the future, if the average advance that has occurred to date in this movement, which started at the beginning of 1915, be taken as unity, then the steel now being shipped is invoiced at an average price representing only between one-fourth and one-third of that advance. It may be concluded that the steel now passing into use or ultimate consumption carries only a small part of the increment in cost that will obtain later if the market holds, even if it does not continue advancing. Therefore, the physical control as to whether high priced steel will pass into consumption with the same freedom as moderately priced steel, is not yet exercised. It is yet to be observed in the future how that physical control will be exercised.

As to the mental, what is in the minds of the two parties, the buyer and the seller, it is obvious there is no control. In the past the sellers of steel have placed a curb upon rising tendencies and have quite freely taken the public into their confidence, to the effect that they would not permit prices to pass above what was considered a safe and reasonable level. To-day they do not maintain such an attitude. Certain legal developments have given them more freedom, and they became imbued some time ago with the belief that steel market strength would last during the war, but in all probability no longer, hence there is no regulating influence that could be exerted, in the matter of prices, to prolong the period of prosperity and active demand. The seller of steel simply adopts the position that the buyer is making the market. It is what would be called in the nomenclature of ordinary times a "sellers' market," but really it is what might be termed, if the nomenclature permitted, a "buyers' market." The typical buyer is regarded as one who beats the price down when circumstances give him a measure of control. To-day he is pushing the price up.

What, then, is the mental attitude of this buyer? He has no precedent. In the past the seller of steel has taken care of him, advancing prices by easy stages, and to no level comparable with the present, for the advance in finished steel products, delivery at mill convenience is now a score of dollars a ton against, say, half a dozen dollars in the preceding three great movements of the steel market, while furthermore with practically every advance the seller has given the buyer an additional contract, for farther and farther delivery, whereas at this time forward delivery contracts are very hard to make. The seller does not look out for the interest of the buyer as he did in the past, and the buyer has no precedent to guide him. He does not know, as a rule, anything about what actual ultimate consumption of steel will be at high prices, and more or less at random he has adopted the practice of bidding for steel, or even of seeking protection as to deliveries at whatever price the mill may choose to name later. The buyer is in a panic, a state of mind described as that of unreasoning fear. There may be the best cause for that fear, but the reasoning is to a large extent absent.

With no important control, physical or mental, exerted at the present time, the steel market's future could not well be more in doubt. The majority of observers expect the pressure for steel to continue throughout the year, and indeed to increase. There are some who expect a break in prices before July 1, perhaps more than one break, for if a break does occur before the end of the war the downward movement will probably be as spectacular as the upward has been, with probably this difference, that the decline will not be continuous, but will be interspersed with periods of recovery. One can reasonably expect such recoveries because there is a "short interest," using stock market parlance, accumulating by projects being postponed when promises of return on the investment are good, but not sufficiently good to warrant outlay at the highest prices.

Pig Iron

The buying movement in pig iron which began about the middle of February has gained some momentum and the market of the past fortnight may be described as decidedly active, with a slight rise in prices. The advance in pig iron from its low point of a year ago has been moderate compared with the advance in steel, both raw and finished, and buyers of pig iron have reason to fear spectacular developments in the market, with practically no limit to advances, while declines could at most only be moderate. The buying is almost exclusively for the second half of the year, buyers being well covered already to July 1. We quote: No. 2 foundry, delivered Philadelphia, $19.75 to $20; f.o.b. furnace, Buffalo, $18 to $18.50; delivered Cleveland, $18.80; f.o.b. furnace, Chicago, $18.50; f.o.b. Birmingham, $15 to $15.50; at valley furnaces, 95 cents higher delivered Pittsburgh; Bessemer, $20.50 to $21; basic, $18.25 to $19; foundry, $18.50 to $19; forge, $18 to $18.50; malleable, $19 to $19.50.

The contract price on English ferromanganese was recently advanced from $150 to $175, seaboard, and only a limited tonnage seems available for fourth quarter, while delivery would be quite uncertain. An acute scarcity of spot alloy developed early in the month, and the needs of smaller users, who do not contract for forward deliveries as do the large consumers, could not be met at rational prices, relative to the contract market, and sales have been made of small tonnages at $300 and upward, with no limit to the possibilities of the next few weeks.

Steel

While the market turnover in unfinished steel is necessarily limited, as the ordinary consumer could not afford to pay prices asked, and must depend on his contract deliveries, at much lower than current prices, there are exceptional cases arising with greater frequency in which the buyer can afford to pay prices asked. For instance, blue annealed sheets, 10 gage, are selling at a higher price than box annealed, 28 gage, and so the market of the one can afford to pay a higher price than the maker of the other. As another instance, there are steel interests, ordinarily self-contained, that can sell forging billets at very high prices, and can afford to buy soft steel, to fill orders for ordinary finished products, at what represents a loss when the conversion cost is added, but which allows another branch of the sales department to score a large profit. We quote as fairly representative of a somewhat elusive market: Bessemer billets and sheet bars, $40; open-hearth billets and sheet bars, $42 to $44; forging billets, $60 to $70; rods, $55; high carbon rods, $75 to $85.

Finished Steel

Regular prices given below are f.o.b. Pittsburgh, unless otherwise noted; where a range is given the lower price is for delivery at convenience of large mills, and the higher for early delivery, from such mills as make a practice of not selling far ahead.

Rails, standard sections, 1.25c. for Bessemer, 1.34c. for open-hearth, f.o.b. mill, except Colorado.

Plates, tank quality, 2.35c. to 3c.

Structural shapes, 2.25c.

Steel bars and bands, 2.25c. to 2.75c., base; steel hoops, 2.50c., base.

Iron bars, Philadelphia, 2.559c.; Pittsburgh, 2.40c. to 2.50c.; Chicago, 2.15c.

Plain wire, 2.25c., base; wire nails, $2.40, base; galvanized wire, 2.95c.; painted barb wire, 2.55c.; galvanized barb wire, 3.25c.

Award of Nichols Medal

Meeting of New York Section of American Chemical Society

At a meeting of the New York Section of the American Chemical Society held on March 10, at the Chemists' Club, the Wm. H. Nichols gold medal was presented to Dr. CLAUDE S. HUDSON of the Bureau of Chemistry, Department of Agriculture. The chairman Dr. T. B. Wagner presented the medal and gave a biography of Dr. Hudson's life. Dr. Hudson then presented a lengthy paper on the "Acetyl Derivatives of the Sugars" describing research work in which he has been engaged and illustrating it by numerous large diagrams. Following this paper a very interesting account of the development of the Bureau of Chemistry and its work was given by Dr. Carl L. Alsberg, chief of the Bureau.

The election of officers for the coming year resulted in a tie vote for the chairman between Dr. J. M. Matthews and Dr. K. G. Falk. The deciding vote of the chairman was cast in favor of Dr. Matthews. Dr. F. J. Metzger was elected vice-chairman and Mr. Charles F. Roth secretary-treasurer.

Corrosion

Joint Meeting of A. I. E. E. and A. E. S.

The problem of corrosion was discussed in two very interesting papers presented at a joint meeting of the American Institute of Electrical Engineers and the New York Section of the American Electrochemical Society on March 10, at the United Engineering Societies Building, New York.

The first was an A. I. E. E. paper on "The Influence of Frequency of Alternating or Infrequently Reversed Current on Electrolytic Corrosion," by Dr. Burton McCollum and G. H. Ahlborn. The second was an A. E. S. paper on "Corrosion and the Engineer," by Prof. W. H. Walker. This paper was read by Prof. W. K. Lewis in the absence of the author.

Prof. Walker after discussing the rather general lack of a clear conception of corrosion on the part of electrical and mechanical engineers took up a general discussion of corrosion.

Corrosion is an electrolytic phenomenon and takes place at ordinary temperatures only in the presence of water. Metallic iron electrically neutral interacts with two hydrogen ions present in the water and which carry electrical charges; an iron ion is produced which takes up the two electrical charges from the hydrogen ions and deposits two atoms of hydrogen.

The factors which influence the corrosion are:

First: The solution pressure of iron. When this is practically nil, as in the case of iron immersed in chromic acid solution, corrosion does not take place. The solution pressure may also be rendered negligible by the impression of an external emf.

The second factor is: The number of the hydrogen ions. The greater the concentration, the more rapid will be the corrosive action. Hence, in the presence of acids, corrosion is accelerated and in the presence of alkalies, it is retarded.

The third factor is: The ease with which the hydrogen ion reaches the iron. For example, an adherent film of iron oxide will protect the metal underneath. Such a film is undoubtedly formed in the case of the copper-steel and accounts for its remarkable resistance.

The fourth factor is: The osmotic pressure of the iron ions. This pressure is usually very small.

The fifth factor is: The deposition of hydrogen and its removal by the depolarizing action of oxygen. This factor is probably the most important of them all. If oxygen be completely removed from boiler feed water, the boilers will not pit nor corrode.

The following members participated in the discussion: Messrs. Alexander Maxwell, Philip Torchio, C. B. Martin, L. W. Chubb, A. S. Cushman (who offered a very interesting discussion), Maximilian Toch, James Aston, A. F. Ganz and F. N. Speller. Written discussion was also submitted by Carl Hering, J. L. R. Hayden, S. M. Kintner and Asa P. Way. A fuller report of the meeting is reserved for our next issue.

The **sodium peroxide** department of the Niagara Electrochemical Company (owned by the Roessler & Hasslacher Chemical Company) was damaged by explosion and fire on March 8. The plant will be rebuilt immediately and new apparatus installed and it is expected to begin deliveries again by May 1.

Electric Tin Smelting in Bolivia.—An interesting development in electric tin smelting is announced in the formation of the South American Electric Smelting Company, which has been organized to smelt tin ores in Bolivia. The new company will take over the equipment of the Standard Smelting Company, Pittsburgh, which was organized for smelting Bolivian concentrates and other tin bearing material in the Wile electric furnace. Three ten-ton Wile furnaces will complete the first installation in South America. These will be placed at different locations on account of the difficulty of shipping ores to one spot. It is expected that these furnaces will be in operation by June 1. Proposed legislation for exclusive smelting and water power rights in Bolivia was the cause of the formation of the new company. Minor C. Keith of the United Fruit Company is president and H. M. Keith is treasurer.

Recent Practice in Concentrating Colorado Tungsten Ores

BY H. C. PARMELEE

Taking them by and large the tungsten concentrating mills of Boulder County, Colorado, have not been inspiring examples of the art of ore-dressing. In fact, to the engineer visiting for the time in this most important tungsten-producing region of the country, some of them appear as marvels of poor construction and bad practice. A probable reason for this is to be found in the history of the industry. Before tungsten became an important product of the district, gold and silver mining ventures had been as numerous as they were unsuccessful. Many mills had been constructed to demonstrate a variety of processes, and a liberal assortment of machinery had been purchased. The result was that when tungsten became recognized as the greatest mineral asset of the county, mill buildings and equipment of a sort were not lacking with which to commence operations on a small outlay of capital. Thus the early tungsten concentrators followed local customs and traditions and adapted themselves in great measure to existing conditions, proceeding along lines not in accord with what would have been considered best practice.

In a previous series of articles[1] the writer discussed the problems of tungsten concentration, described the existing practice at all of the mills and gave some data bearing on the magnitude and importance of the Boulder County production as compared with that of the United States. The county still holds its premier position among tungsten-producing districts of this country.

At the time the articles mentioned were written, the newest mill was that of the Primos Company, the features of which were crushing in stamps, and concentration on Wilfley tables, vanners and stationary canvas plant. The latter had an area of about 10,000 sq. ft. The other important mill was the Wolf Tongue, which was the first to adopt the jig and minimize the use of canvas tables, but it was not a model plant. In fact there was at that time no mill in the district working along lines meriting general approval.

Criticism of Grinding Methods

Adverse criticism of the milling practice has been leveled mainly at the use of stamps for crushing. The basis for this will be found in considering the physical properties of ferberite, the principal tungsten mineral in Boulder County ores. This mineral is brittle and friable, and has a specific gravity of 7.2-7.5. The gangue is tougher and lighter. Thus when the ore is crushed in stamps, the heavy friable mineral remains too long in the mortar and is ground finer than necessary, producing a needless amount of slime. By the time the tough gangue is crushed fine enough to pass the screen, the soft heavy mineral is much finer, and some of it is of the consistency of paint. The criticism holds good for any grinding machine that affords a settling pocket for the collection of heavy mineral.

With such preliminary treatment, an elaborate slime-recovery plant follows as a necessity; but if the ore were crushed in a different manner, as by rolls, the ore-dressing scheme would be altered. By the use of jigs a large part of the mineral would be recovered in coarse, high-grade form, and on regrinding the jig tailing and classifying the pulp the balance could be recovered in a large measure on sand and slime concentrating tables of approved types. Stationary canvas tables might be dispensed with entirely, and in any event very little reliance need be placed in them.

In making these comments it is not forgotten that there are some ores in the district in which mineral is finely disseminated, wholly unsuited to jigging and extremely difficult to concentrate by any means. The suggestion of roll-crushing and jigging for these tungsten ores is not new and has been made frequently, but until recently no opportunity was afforded to put it into practice.

The present demand for tungsten, however, and the attractive prices offered for concentrates have stim-

[1] This journal, July and August, 1911.

FIG. 1—CONCENTRATING MILL, BOULDER TUNGSTEN PRODUCTION COMPANY

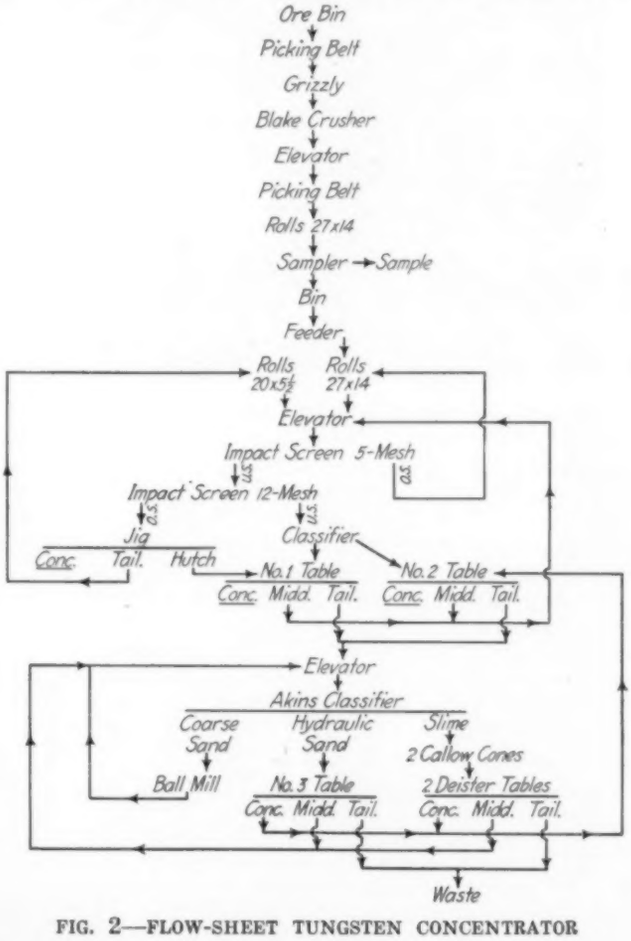


FIG. 2—FLOW-SHEET TUNGSTEN CONCENTRATOR

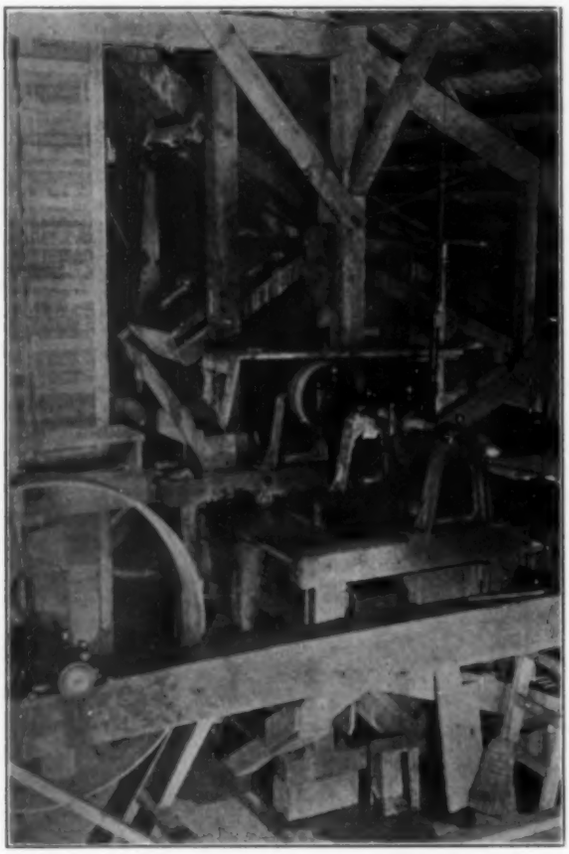


FIG. 3—SCREENS AND JIG

ulated production as never before. Boulder County has seen more activity than for several years past. Prospectors have been numerous and diligent; some lessees are enriching their output with hand jigs; one or two old idle mills have been pressed into service or are being remodeled for concentrating purposes; and at least one new one has been built. Prosperity is in evidence on all sides; buyers are plentiful and in active competition bidding for concentrates. It was under the stimulus of these conditions that the Boulder Tungsten Production Co. built the modern 40-ton concentrating mill shown in Fig. 1.

New Mill of Boulder Tungsten Production Co.

The structure was erected near the mouth of the tunnel through which the mine is worked, on a site just below the Nederland dam of the Colorado Power Co. The cost of the mill, fully equipped and running, was about $18,000; and such is the state of the tungsten industry at the present time that within four weeks of the day the mill was started, and working only two shifts per day, its entire cost had been recovered in the value of products sold. And such a record was accomplished with mill feed averaging about 1 per cent WO_3, and sometimes less.

The coarse crushing, grinding and sampling equipment has a capacity of 75 tons, the balance of the mill 40 tons, per 24 hr. Electric power is used throughout. The flowsheet, Fig. 2, gives an outline of the equipment and treatment, the features of which are roll-crushing, screening, jigging, hydraulic classification, ball-milling and table concentration. There are no stationary canvas tables. The only grinding machine in the

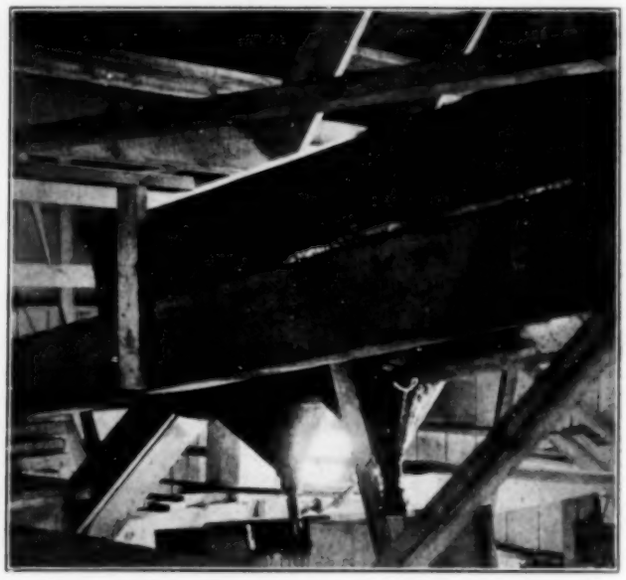


FIG. 4—AKINS CLASSIFIER WITH HYDRAULIC COMPARTMENTS

system that would afford a pocket or lodging place in which tungsten mineral might remain and be ground unduly fine is the ball-mill, and this is of the rapid discharge type. Furthermore, it receives only sand tailings from the concentrating tables, after free mineral has been removed. Otherwise all grinding is done with rolls, and after each reduction in size the pulp is dressed for the recovery of free mineral. All middlings are kept in closed circuit, and the only tailings rejected are those from the slime tables.

Roll Crushing and Sampling

Two short picking-belts are in use, one each before and after crushing to 1 in. The next reduction in size is by rolls to ¼ in., at which size the ore is sampled. The Vezin sampler first installed is to be replaced by a horizontal traveling-bucket sampler, which can be better adjusted to the local requirements. In this sampler the buckets are supported between endless traveling chains, and the quantity removed for sampling can be adjusted by varying the number of buckets or their rate of travel. The sample is delivered by gravity to the coning floor, which is covered with sheet steel. Here it is coned and quartered and finally ground for assay.

There is a storage bin for the ¼-in. roll product

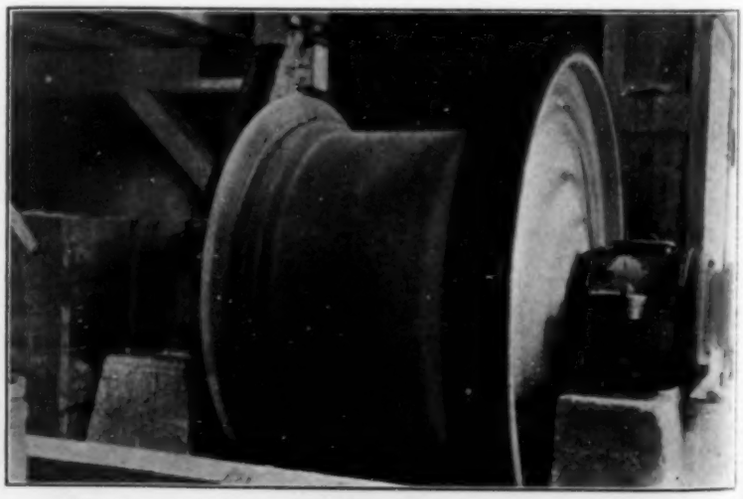


FIG. 5—BALL MILL, SCOOP FEED AND RAPID DISCHARGE

rejected by the sampling apparatus, and from this bin a plunger feeder supplies the rolls which crush to about ⅛ in. This product is elevated and passed over two impact screens, 5-mesh and 12-mesh respectively, the undersize of the first going to the second. The 5-mesh oversize is returned to the rolls. The product, — 5 + 12 mesh, is jigged, and the — 12 is classified for table treatment.

Importance of the Jig

The jig is a useful machine in concentrating most Boulder County tungsten ores, and its omission in earlier mills is a point of adverse criticism. The great point in its favor is the recovery of a high-grade concentrate in coarse form. Compared with jigs in lead or copper mills, the two-compartment machine at this plant may seem to be doing little or nothing; but in all the local tungsten mills the output of concentrate is measured in pounds rather than in tons, and it is far better to obtain as many pounds as possible in coarse form than to grind the mineral to paint and endeavor to save it on canvas. At this mill the jig concentrate is recovered by skimming several times a day, by-passing the feed during the operation. No provision is made for continuous discharge of concentrate, as it does not accumulate in sufficient quantity. Jig tailing is reground in separate rolls and returned to the elevator and screens. The small amount of hutch product is sent to the coarse concentrating table, as mentioned below.

The jig is of the Harz type, running with ½-in. stroke at 240 r.p.m.. In the first compartment the screen is 12-mesh, and in the second 14-mesh.

For table concentration the minus 12-mesh pulp is classified in a two-compartment hydraulic spitzkasten, the products flowing to two tables. To the coarsest grade is added also the hutch of the jig. These two tables make finished concentrates; middlings which are returned to the screens, and sand-slime tailings which are treated in an Akins classifier. The latter machine, in addition to making the customary sand-slime separation by the revolving helix, is equipped with hydraulic hoppers at the lower end for the removal of fine sand from the slime. Thus the machine in this case delivers coarse dewatered sand for regrinding, fine sand from the hydraulic hopper, and slime overflow.

Regrinding in Ball Mill

The coarse sand is reground in a ball mill, 4 ft. in diameter and 3 ft. long. This machine is of the modern type with a discharge compartment containing radial lifters, separated from the grinding compartment by a grating. The grinding medium is 2-in. steel balls, and the lining is hard white iron. The ball-mill product flows to an elevator and back to the Akins classifier. It is the intention to grind all sand to minus 40-mesh, but as the mill is not always loaded to capacity the grinding may be as fine as 50-mesh.

FIG. 6—SLIME CONCENTRATORS

FIG. 7—TRANSPORTATION OF TUNGSTEN CONCENTRATES, LOAD VALUED AT $10,000

Redressing Slime Concentrates

The fine sand from the Akins classifier is concentrated on a Wilfley table, while the slime overflow is thickened in two 7-ft. Callow cones and treated on two Deister slime concentrators. During the first month of operation these three tables made finished concentrates and tailings, and middlings which were returned to the classifier. Under those conditions five grades of concentrates were being made, as follows:

Product No.	Machine	Per cent WO_3
1	Jig	60
2	No. 1 table	54
3	No. 2 table	45
4	No. 3 table	35
5	Deisters	28

Just recently, however, a change has been made by Mr. W. A. Kunkle, mill superintendent, which reduces the number of products from five to three and at the same time raises the average grade of all products without lowering the percentage recovery. This has been done by redressing products 4 and 5 on No. 2 table. Products 4 and 5 are low-grade mainly by reason of contamination with silica, and their retreatment gives No. 2 table a heavier load and permits a cleaner cut of finished product. Since the middling is in closed circuit, a high-grade product can be cut without fear of loss. The effect of the change has been to raise the grade of product 3 to about 50 per cent, at the same time increasing the quantity and eliminating the two low grades. Under the changed conditions the products are as follows:

Product No.	Machine	Per cent WO_3
1	Jig	60
2	No. 1 table	54
3	No. 2 table	50

At the present time the recovery is averaging 87 per cent. The importance of jigging is indicated by the fact that the first two products, from jig and coarse table, represent 85 per cent of the total recovery. Further, these concentrates are the highest grade products, although since the above-mentioned change was made there is really no low-grade concentrate coming from this mill. In fact it is safe to say that no mill in the district is excelling this one in percentage recovery, and that probably none is equalling it in average grade of total product. The best canvas-table concentrate will rarely exceed 40 per cent WO_3, while under present conditions it is likely that nothing lower than 50 per cent is being made at the mill under consideration.

We are indebted to Mr. J. G. Clark, manager, and Mr. W. A. Kunkle, mill superintendent, for the information here presented.

Potash from Kelp

A Record of Handling Kelp in Commercial Large-Scale Operation

BY I. F. LAUCKS

The scarcity of potash, due to the war, has caused great interest to be taken in any of its possible sources. One of these is the growths of kelp on the Pacific Coast, about which there has been much written in the popular press, but very little authentic information in the technical papers, outside of data regarding the composition of the plants.

The United States Government has done considerable work on kelp, but practically all of it has been confined to analytical data on the dried material.

Before this year most of the companies attempting to develop the kelp industry have been of limited capital. Only lately have several concerns with plenty of money to carry their development through to a successful issue engaged in this industry, so that at the present time a limited amount of dried kelp is being produced, and we may shortly expect a considerable increase in this production.

The experience detailed in the following paper has been confined entirely to the kelp of Puget Sound, the species "Nereocystis Luetkeana." The author has had direct charge of large-scale operations, harvesting, transporting and drying this kelp, and any value which these observations may have is because they are records of actual experience. Outside of the composition of the plants, most of the experience would be applicable to California kelp as well.

COMPOSITION OF KELP

The green kelp plant is mostly water. This applies to most of the Pacific species, and especially to "Nereocystis." Analyses have shown as high as 95 per cent water. The average is probably between 92 per cent and 93 per cent. A great deal of disappointment has been caused to several concerns in this locality, who accepted the estimate of the Department of Agriculture that ten wet tons would make one dry ton. While this probably applies to California kelp (Macrocystis), it certainly does not hold for "Nereocystis."

To compensate in a measure for the larger amount of water, the Northern plant has a higher content of potash in the dried material.

For analytical data on kelp the reader is referred to publications of the United States Department of Agriculture and the University of California Experiment Station, and especially to Bulletin No. 248 of the latter.

CONDITIONS OF GROWTH

The "Nereocystis" is an annual plant, that is, it grows anew every year. The young plants reach the surface of Puget Sound waters in May and June. Some hold to their moorings the whole year, but most of them are washed away by storms by the end of February or March. They are attached to the bottom by a "hold fast," resembling the root of a land plant, but having none of its functions, other than to serve as an anchor. The plant grows from spores or seeds, which are dropped in August or September. A bed of kelp should not be completely cut away before the seeding time, or it might not be renewed the next year.

The best beds are found where the bottom is favorable for attachment, as rocks or hardpan. They also need a strong tide current to renew them.

The stem of the plant extends from the bottom to the surface, and stretches out on the surface up to ten or fifteen feet at low tide. The stem is cylindrical, hollow, filled with air, with walls up to one-half inch in thickness, and grows larger toward the upper end, terminating at this end in a bulb sometimes nearly half a foot in diameter.

From the bulb extend leaves, like ribbons, several inches wide, which grow as long as twenty feet. Ordinarily the bulb floats on the surface. The leaves, however, having no air to buoy them up, are somewhat below the surface, except when a strong tide current is running. Sometimes, also, the whole plant is dragged below the surface by a tide current.

Some of the beds form a thick, tangled mat of plants over the whole surface. In others the plants grow in bundles or sheaves, with open water between each bundle. Up to thirty or forty plants may compose such a bundle. Often a bed of kelp will have a rock in its center, which increases the difficulty of harvesting, or it may fringe a rocky shore very closely, so that not all kelp beds are commercially available by any means.

The stem and leaves are both soft enough to cut very

FIG. 1—NEREOCYSTIS

FIG. 2—KELP BED, PUGET SOUND

easily with a cutting edge having any motion, except the lower ends of the stems, which are considerably tougher.

HARVESTING

The great question in the utilization of kelp has always been the cost of harvesting. There was no reliable way of prophesying what it would cost to go out in the ocean, cut a plant below the surface of the water, get it aboard a scow and bring it back and unload it at a dock. As for the other features of the process, they were well known. Data on drying costs, leaching, crystallizing, etc., were available, but no one had ever before harvested a marine plant in hundred-ton lots.

There have been a number of different types of machines proposed for cutting kelp, including reciprocating knives, revolving blades, band saws, etc., but so far as the writer is aware the only method which has been tried in actual practice is that of reciprocating knives (like a mowing machine). These operate several feet below the surface of the water and may be made as wide as desired. A conveyor of some type is usually placed behind the knives to carry the cut kelp aboard the scow. After it is aboard it is generally chopped into shorter lengths by various machines, and piled either on the scow which carries the cutting mechanism or another scow alongside.

The harvester described herewith has a cutting capacity of one hundred tons of green kelp in six hours, at high tide. At low tide the cutting rate is considerably greater than this, as more of the plant is on the surface. Two men operate the rig, with the exception of unloading, in which extra help is required. They live aboard the harvester and do their own cooking.

One man stands on a bridge across the conveyor in front. It is his duty to watch for drift wood and keep it away from the conveyor with a pike pole. The other man has a general oversight of all of the machinery, and is available in emergencies. The kelp requires no actual handling at any stage on the harvester except in the unloading.

The cutter knife was made by joining two 6-ft. McCormick harvester knives end to end, making a 12-ft. knife, and slides on a guard bar made of a standard channel. The standard McCormick fingers and guards were attached to this bar. This knife in its cutting position is horizontal and 4 ft. below the surface. At each end of the horizontal knife is a vertical knife 5 ft. long, which reaches above the surface of the water. All three knives are driven together by an eccentric rod on the front end of the frame which carries the conveyor. This frame is made up of angles and channels, and carries the shafts and sprockets on which the conveyor runs. The conveyor is the same width as the cutter knife, and consists of a sprocket chain on either side, carrying wooden flights. Fish netting is fastened on the flights, and special attachments to pick up the kelp after it is cut.

As the kelp is cut it is carried back against the conveyor by the motion of the boat, and immediately picked up. The conveyor gathers up practically all of the cut kelp. Also all of the plants coming between the ends of the cutter knife are cut.

The conveyor is pivoted on a horizontal shaft so that it, with the knives, can be raised when cutting is finished. The conveyor dumps the plants into a bin at the bottom of which is a chopper. This chopper is 11 ft. long, and resembles a lawn mower. It was built by mounting six Ohio alfalfa cutter knives end to end on a shaft. The kelp is cut into lengths from 3 in. to 18 in., depending on the angle on which it falls into the cutter. This cutting is done merely for convenience in unloading, as it is entirely impractical to handle the full length stalks with their attached leaves.

From the chopper the cut kelp falls into another conveyor 18 in. wide, which delivers 20 ft. above the deck of the scow. The kelp falls in a heap on the deck, and as the heap grows in height it gradually flows outward until it distributes itself uniformly in a cone-shaped pile over the loading space, without any handling.

Gates are fastened to the sides of the scow and to the stanchions, which hold the kelp aboard. One hun-

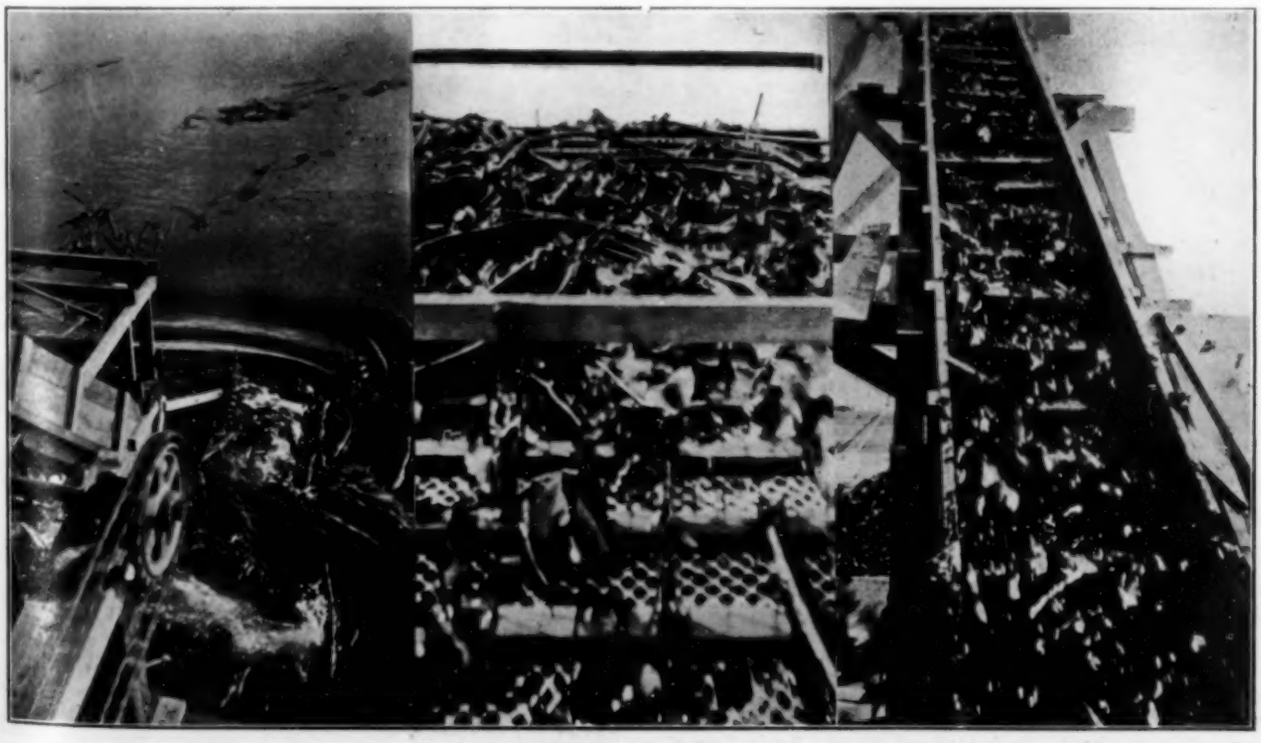


FIG. 3—SIDE VIEW CUTTER KNIFE

FIG. 4—KELP ON CONVEYOR FROM WATER

FIG. 5—KELP ON CONVEYOR FROM CHOPPER

dred tons of kelp will make a pile 8 or 10 ft. deep in the center and 5 or 6 ft. at the sides.

The scow is 90 by 28 ft., and 6 ft. deep. The machinery and living quarters take up 30 ft. forward. Fifty-five feet aft carries the kelp, and has a capacity of 200 tons. A 20-hp. Fairbanks Morse gas engine drives the entire rig.

In fairly quiet water the tug is tied alongside the scow, as it can be steered more positively in this position. In rough weather the tug takes a line from the forward corner of the scow, so that the scow stands at an angle to the direction of the tug. In ordinary weather a 60 to 80-hp. gas boat is sufficient to handle the scow and tow it back and forth at a rate of five to six miles per hour. During cutting the scow is moved as fast as possible by the tug. The kelp impedes the motion both by its resistance to the scow and tug and by entangling in the propeller of the tug.

During all stages of tide, except slack water, the current strings the plants out in fairly parallel lines. The most efficient cutting is done when the scow is running in the same direction as the plants. It makes little difference whether running with or against the tide. In small beds considerable time is lost in turning around, which must be done outside the bed. In larger beds the harvester can be turned inside the bed, so that cutting is not interrupted.

The harvester described has been operated in fairly severe weather conditions, with waves running so high that they continually broke over the forward deck of the scow. Such weather does not materially affect the speed of cutting.

The cost of cutting is mainly composed of the towing charge. This can be reduced considerably by mounting the cutting machinery on a self-propelled barge. In such an arrangement the same crew which at present is required on the tug could operate the entire harvester. Such a boat would have a further advantage of being more easily and positively handled.

COST OF HARVESTING

The costs herewith given are from actual operating figures. They are based on gathering 100 tons every 24 hr., that is, making one round trip per day between plant and beds.

	Per day
Labor—	
One man	$3.00
One man	2.00
Provisions	1.50
Distillate and oil for power	1.50
Tug	30.00
Interest and depreciation	5.00
Total per day for 100 tons	$43.00
Per ton	.43

The above cost holds for a distance of about twenty miles between the beds and the plant. For shorter or longer distances the cost is proportionately decreased or increased, as a smaller or larger tug is necessary. It will be noted that 30 cents per ton of the above cost is the towing charge.

The plan has been proposed of mounting the cutting machinery on one scow and carrying the load on another. The two would be lashed together during cutting. This idea appears impractical from the writer's experience. The handling of one scow by a tug in a kelp bed is hard enough without complicating matters by adding a third unit. In rough weather it would be very difficult to keep the two scows side by side. The harvester can be built for about $6,000, including the hull.

UNLOADING

Two methods have been tried out, by hand labor and by the use of a drag scraper. The plant has a conveyor running out into the water, at a slope of 2 in. per foot, and long enough so that the outer end is under water at low tide. The scow can therefore always be laid alongside of some portion of this conveyor at any stage of the tide. The conveyor is simply a trough 3 ft. wide with a coil chain, to which are fastened 2 x 4-in. wooden flights, dragging along the bottom. The gates on the sides of the scow are hinged on the deck line, and when the scow is laid alongside the conveyor, are let down to form chutes from the deck of the scow over to the conveyor trough.

As the kelp is piled up 5 or 6 ft. deep at the sides of the scow, and is quite slippery, a considerable amount of the load can be slid off as soon as the gates are lowered with very little labor. The balance is then slid across the deck to the chutes by hand. Scrapers resembling a snow shovel or scraper are the handiest tool for hand unloading. The deck is very slippery, and a scraper slides easily. The men need corked shoes to prevent their slipping. Six men unload one hundred tons of kelp in six hours by this method.

We have tried the use of drag scrapers to move the kelp across the deck to the chutes. A 7-cu. ft. scraper handles several hundred pounds of kelp at one load. We discontinued this method of unloading temporarily because of lack of a winch to properly wind the scraper drag line.

The cost of unloading by hand is:

Four additional men at 25c. per hour, 6 hr. each	$6.00
Power	0.35
	$6.35
Per ton	$0.063

The power cost above includes conveying a distance of 320 ft. along the dock with a raise of 35 ft. to the bin, done by the same conveyor mentioned above.

We have designed a system of conveyors to be installed on the deck of the scow, which will unload it without any additional labor cost, the two men operating the scow also operating these conveyors. This will reduce the cost of unloading to less than 1 cent per ton.

CONVEYING

The cheapest and most satisfactory type of conveyor is the chain conveyor with wooden flights and either double or single chain. The kelp is slippery enough to lubricate the trough, so that the power requirement is low. Bucket elevators and screw conveyors have also proven satisfactory.

BINS

The bin at the plant under discussion has a bottom slope of 1 in 2.66 and is lined with rough lumber. This

FIG. 6—100 TONS KELP ABOARD HARVESTER

slope is just sufficient to cause the kelp to slide very slowly as it piles up at the upper end. In smooth metal-lined chutes kelp will just slide on the same slope when dropped into the head of the chute periodically as the discharge from a conveyor. When it accumulates in such a chute it slides readily.

Bins should be water-tight with provision for drainage to the dryer. When cut kelp is stored in a bin its own pressure is sufficient to squeeze out considerable liquor, which carries potash in direct proportion to its weight. After the second day in warm weather the kelp begins to decompose, and the loss of liquor is then much greater.

Cut kelp piles to a depth of a foot or two averages 40 lb. per cubic foot. When piled to a depth of 6 or 8 ft. as in a bin it is compressed and weighs as much as 60 lb. per cubic foot.

Drying

The direct-heat rotary dryer appears to be the most satisfactory type of dryer for kelp. It is necessary that the kelp be reduced to a uniform size before being fed to a rotary. That is, the leaves of kelp are very thin and present a great surface in proportion to their weight, while the stems are thick and fleshy. If fed to a rotary the leaves are quickly dried, while the stems come through so wet that free liquor is still present, and this happens with a dryer as long as 60 ft. These consequently have to be returned several times. If, however, the whole feed is shredded, then the drying is nearly uniform and very little, if any, of the product has to be returned. The product of the dryer with such a feed is fine enough so that it needs no further reduction to mix with other fertilizer materials.

As kelp carries about 2 per cent of nitrogen, under certain circumstances it is worth while to take precautions to prevent loss of nitrogen by burning in the drier. This can be done by feeding the green kelp at the fire end of the drier and regulating the feeding so that the moisture content of the product is between 5 and 10 per cent.

The dust problem in drying is a serious one, and a drier must be provided with efficient dust collectors. As much as 20 per cent of the weight of the product has been collected from the dust chambers in test runs. The method of spraying the dust with water and settling and redrying the product, which is in common use in fertilizer drying plants, cannot be used with kelp because of leaching the potash. Large chambers where the velocity of the air is much retarded are efficient.

In sacking and handling the dried product the dust is also very troublesome, as it is very pungent and irritating. Men working in it need to be provided with respirators. It also leaks through ordinary fertilizer or sugar sacks very easily. A paper-lined sack is best. The sacked material will weigh practically the same as fish meal.

The capacity of a 50-ft. drier is stated by manufacturers to be 3.6 tons of water per hour. This amounts to 3.9 tons of green kelp. Test runs have proven this estimate to be substantially correct.

Oil is the most economical fuel for the kelp fields of the California cost. In the Puget Sound district there is available an immense amount of waste wood from the lumber mills. As most of these mills are located on tide water and many of them very near the kelp beds, this cheap fuel makes a very favorable condition for the utilization of Puget Sound kelp.

By "hogging" or shredding this waste wood it can be burned with as low a labor cost as oil. It can be readily transported to any desired point by scows. The wood ash carries some potash which can be mixed with the dried kelp.

For reducing the green kelp to uniform size for feeding to a rotary, the Williams hammer type mill has been found very satisfactory. The product is very finely comminuted, its appearance being best described by the term "chewed up." Considerable liquor is set free by this shredding. Shredding in corrugated grooved rolls, with one roll running considerably faster than the other, has not proven satisfactory. The pieces tend to flatten out and are not sufficiently shredded. Other types of machines may be found satisfactory for this purpose, but the two above mentioned are the only types we have had opportunity to try. For grinding the dried product the hammer type mill is also very satisfactory. Factory tests of other types, as disks and rotary knives, have also been favorable. As before mentioned, if the feed is ground the product will need no further grinding. Large pieces of kelp stems dry to leathery consistency. These grind readily in a hammer mill.

As before mentioned a large percentage of the water in kelp squeezes out under its own pressure, when piled to any depth. This may also be squeezed out mechanically. Hand tests have squeezed out as much as 75 per cent of the water, and with it 75 per cent of the potash content. A machine of the type of the hydraulic press or a filter press would do better than this, but the labor cost would probably be prohibitive.

A trial of a 36-in. screw press was unsatisfactory, very little juice was squeezed out. The kelp fed had however already lost some of its water in shipping, so that this might not hold for fresh kelp. Rolls squeeze out some water but it is difficult for rolls to nip pieces of kelp unless they are set to at least $\frac{3}{8}$ of an in. apart, so that their squeezing action is much lessened.

If a cheap means can be developed for squeezing out part of the water, this water might be more economically evaporated in a multiple effect evaporator. The liquor, however, contains considerable organic matter both in suspension and in a colloidal solution. This might seriously affect the working of such an evaporator.

Patents are pending to Falckenburg & Laucks for a method of piling kelp in high towers, allowing it to partially decompose and squeezing the liquor out by its own pressure. The liquor would then be run to shallow ponds and allowed to evaporate by sun and air. The organic residue would be dried artificially. This method is applicable to hot, dry climates.

Kelp dries very readily when spread out in a very thin layer in the sun and air. Each plant must practically be kept separate by itself. If two are superimposed, the lower will not dry. If too close together drying is very slow. The labor cost of spreading and collecting and the acreage necessary make this method prohibitive.

The cost of drying will vary between 25 and 50 cents per ton of green kelp, depending on the fuel used, cost of power, size of plant, etc.

It is not necessary to go further than the dried kelp to obtain a marketable product. The potash and nitrogen are saleable on a unit basis. If there is a local market for these for fertilizer purposes, it would probably not be advisable to carry the operation further. If, however, the market is at some considerable distance with high freight rates, it is more profitable to concentrate the valuable ingredients and save freight charges on the valueless ingredients, as the sodium chloride and non-nitrogenous organic matter.

Assuming 28 per cent chloride of potash and 2 per cent nitrogen, in the dried material, about 60 per cent of the weight is practically valueless. If the material is shipped from the Pacific coast to the Atlantic by

water, the nitrogen will just about pay the freight by water in ordinary times. If the potassium chloride is concentrated from the balance, the nitrogen can be sold in the Pacific coast, and 70 per cent of the freight saved on the potash. The latter plan will be more profitable, except when the price of potash is very high, when the necessary loss of potash in leaching and purifying may counterbalance the saving in freight.

There has been some objection by fertilizer dealers that the nitrogen of kelp was not in the available form. When measured by the ordinary empirical methods for determining the availability of nitrogen it does not show a high availability. The methods used, however, are adapted to materials whose nitrogen content is much higher in proportion to their total organic (reducing) matter than is the case with kelp. If the method is altered to fit the changed conditions of kelp, the nitrogen is shown to be as available as other nitrogenous fertilizing materials and this has been borne out by all crop tests. In addition the high organic matter of kelp is valuable in furnishing humus to soils.

There have been a number of proposals for obtaining pure potassium chloride (and sulphate) from dried kelp. The dried material is readily leached, yielding a high percentage (95 per cent) of its potash contents to counter-current leaching. The potassium chloride can be readily separated from the sodium chloride by crystallization after several methods. There is no difficulty in obtaining as high as 95 per cent potassium chloride in the first products of crystallization.

It has been proposed to dry-distill, or retort the dried kelp, recovering the nitrogen as ammonia from the gases (along with acetone, creosote, etc.), and to leach the residue to obtain the potash. This will probably fail because so far the yield of ammonia has been very low while the cost of the method is high. The ammonia is the only gaseous product of any importance.

Most processes for recovery of the potash in fairly pure form, also take account of the iodine. This is left in the mother liquors after crystallizing out the potassium and sodium and can be obtained by ordinary methods for iodine recovery. It is stated that iodine recovered from Japanese kelp is a considerable factor in the United States market.

There is one other product of kelp which shows some promise of being valuable. This is the colloid, glue like substance called algin, which is present in most Pacific coast species. A number of uses have been proposed for it, but a considerable amount of research and development is necessary before any profits can be calculated from this source.

With the present high price of potash, the drying of kelp is a very profitable business. Such conditions will enable the industry to get a start and work out its problems. With normal prices of potash, kelp must be worked in plants of large capacity, well designed, with a minimum of labor, and every possible economy effected. All of the profitable by-products must be saved. It would seem unlikely that the price of potash will be lower for some time than it was before the war. If the price remains above $35 per ton for 80 per cent muriate of potash, kelp can be worked at a profit in a properly designed plant.

Falckenburg & Laucks,
Seattle, Washington.

Metallurgical Progress in Peru

In a paper by MICHEL FORT, presented before the Second Pan-American Congress in Washington, D. C., an interesting account is given of recent progress in metallurgical practice in Peru.

The metallurgical industry in Peru is only about twenty-five years old, and has developed rather slowly. Before 1889 gold washing and occasionally lode mining were practiced by very primitive methods, and amalgamation of silver and gold ores by the patio process was used to some extent, especially in Cerro de Pasco.

In 1889 the author of this paper started at Casapalca the plant known as *Metalurgia Moderna*. At first there was but one five-stamp mill, and the auxiliary appliances consisted in Blake mills, Hartz jigs, Frue vanners and revolving tables. The plant was very successful, and was enabled to utilize large quantities of abandoned ore. Later, in 1894, the writer designed and installed a plant at Aguas Calientes. After this a great many others followed, in which several modern improvements were introduced. They were originally intended for the treatment of silver ores, usually associated with galena, chalcopyrite, and especially blende. As nearly all silver ores contain gold in the form of sulphides and tellurides, many of the silver mine companies have appliances for gold concentration, the concentrates being either exported or treated by cyaniding.

The smelting works of Casapalca were probably the first to use crude oil in ordinary reverberatory furnaces. Later they undertook the smelting of lead ores, and still later copper ores. The reverberatory furnaces were first replaced with Brown roasters, and more recently by agglomerating pots. To-day the plant carries its work to the casting of copper bars, containing some gold and silver, for exportation.

The largest and most important smelter in South America is the Tinyahuarco smelter, also in Cerro de Pasco. It was started in 1900 and has all modern appliances, including coke apparatus, MacDougal roasters, water jackets, Smith converters, and all the necessary auxiliaries. Power is obtained from enormous hydroelectric plants, from which is also derived the power required in all mining operations. The plant works copper ore of as low a grade as 5 per cent, the finished product being in the form of bars.

Cyaniding has been tried with both gold and silver ores, but on the whole with little success. At present it is planned to install a cyaniding plant in Pataz for the treatment of auriferous pyrites. Careful tests show that about 95 per cent of the gold can be extracted from this ore.

Bismuth in bars is now produced in one of the Cerro de Pasco plants.

The paper gives a long list of all the metallurgical plants in Peru, including those for handling and preparing the ore, smelters, and amalgamation, leaching and cyaniding plants. It closes with a description of the metallurgical laboratory of the Engineering School of Lima.

Progress in Glass Making

Program of Next Meeting of New York Section of Society of Chemical Industry

The next meeting of the Society of Chemical Industry, New York Section, will be held on Friday evening, March 24, at the Chemists Club. The subject for the evening will be "Glass," and the following papers will be presented:

"Development of Low Expansion Glass," by Dr. E. C. SULLIVAN of the Corning Glass Works, Corning, N. Y.

"American Pressed and Blown Glass and the Table Ware Industry," by S. R. SCHOLES of the Mellon Institute, Pittsburgh, Pa.

"Glass We See Through," by G. OSGOOD ANDREWS, special representative of the Plate Glass Manufacturers of America.

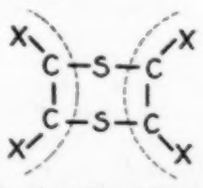
The Reclaiming of Rubber Waste

BY ANDREW H. KING

"Old rags, rubbers, and old gum boots" has been the cry of the rag man for generations. It is by such men that modern efficiency reaches into every nook and corner of the country for worn out rubber goods. Such material has a value, not only to those interested in its recovery, but to society as well, since the reclaimed product or shoddy replaces new rubber either wholly or in part in thousands of instances, thus leaving a larger portion of the supply for the production of high grade articles, such as tires. Were it not for the shoddy industry, the supply would be considerably short of the demand, and the resulting prices would place rubber articles beyond the reach of many people. In fact, the rubber tired automobile would be a luxury rather than the necessity that it has come to be. I do not wish to give the impression that shoddy, as it is now made, is anyway nearly as good as new rubber. It has a much lower tensile strength, elasticity, and wearing power, but its properties are sufficient to fit it for many uses to which it is applied.

In my previous articles in the issues of January 1 and 15 of this journal I endeavored to show how rubber is reinforced with cotton for the production of many useful things. The first concern of the shoddy manufacturer is the removal of this fabric. This is accomplished by the use of various reagents which convert the cellulose to water soluble forms. The next step is to make the rubber, which here consists of caoutchouc and fillers, soft and plastic. It must be capable of mixing with more fillers, such as sulphur, litharge, etc., and of further vulcanization. A true reclaiming process would return the rubber in its original state, but so far this has been impossible.

Vulcanization, as has been stated, consists primarily of the union of sulphur with the rubber hydrocarbon. The degree of vulcanization is dependent upon: first, the quantity of sulphur present; second, the time and degree of heat used; and third, upon the presence of various accelerators. Like all chemical reactions, mass action plays a considerable part in determining how much sulphur shall unite with the rubber. There is always some free sulphur; that is, sulphur extractable by solvents such as acetone. That which cannot be extracted we call combined sulphur. Weber considers that the true vulcanizing effect consists not only in the formation of an addition product, but also a conjugation of india rubber molecules as well. He illustrates thus:



Vulcanization always takes place in steps. Axelrod claims that it consists of two distinct processes: first, the action of heat on rubber, which tends to depolymerize it; and second, the entry of sulphur into the rubber molecule. Since the removal of the combined sulphur is as yet impossible, the rubber chemist has done the next best thing, which is to depolymerize the waste according to Axelrod's idea.

Every process, with but few exceptions, consists of two steps; first, the destruction of the fabric by hydrolysis; and second, the depolymerization of the rubber.

In order to give an idea of the relative value of different grades of rubber scrap, the New York prices for Dec. 30, 1915, are quoted below. These prices are for carload lots delivered:

Boots and shoes	10¼c. lb.
Trimmed arctics	8¼c. lb.
White tires, Goodrich and Goodyear	7⅝c. lb.
Auto tires, standard white	5⅞c. lb.
Auto tires, standard mixed	5⅝c. lb.
Auto tires, stripped unguaranteed	3½c. lb.
Auto peelings, No. 1	9 c. lb.
Auto peelings, No. 2	7¾c. lb.
Inner tubes, No. 1	27 c. lb.
Inner tubes, No. 2	12¼c. lb.
Inner tubes, red	12½c. lb.
Irony tires	2 c. lb.
Bicycle tires	3¼c. lb.
Solid tires	5¼c. lb.
White scrap, No. 1	11½c. lb.
White scrap, No. 2	9¼c. lb.
Red scrap, No. 1	5½c. lb.
Red scrap, No. 2	7¼c. lb.
Mixed black scrap, No. 1	3¾c. lb.
Mixed black scrap, No. 2	3 c. lb.
Rubber car springs	3½c. lb.
Horse shoe pads	3⅝c. lb.
Mattings and packings	1 c. lb.
Garden hose	1¾c. lb.
Air brake hose	5¾c. lb.
Cotton fire hose	2¼c. lb.
Large hose	1½c. lb.
Hard rubber scrap, No. 1, bright fracture	23 c. lb.
Battery jars, red	2½c. lb.
Insulated wire stripping	2⅞c. lb.
Rubber heels	3½c. lb.

Scrap may be classified as follows:

I. Fabric free.—This class includes all grades of scrap which consist of pure compounded rubber, that is, rubber compound containing no cotton, wire, iron studs, etc. Under this head comes inner tubes, auto tire peelings, druggists' sundries, etc.

II. Fabric bearing.—This class includes those grades of scrap containing fabric, wire, etc. Hose of all kinds, boots and shoes, stripped tires, etc., are included in this class.

III. Ebonite.—Under this head comes all hard and semi-hard scrap, such as hard valves, sundries, etc.

As would be expected, the treatment differs for each class.

FABRIC FREE

This is, without doubt, the easiest class to reclaim. In fact, there are numerous instances where such material is added directly to rubber mixings. Reclaiming consists simply of softening and depolymerizing the scrap. The finely ground material is mixed with vaseline, tar, carbolic acid, or heavy mineral oil either alone or mixed with rosin. This mixture is heated in live steam at 300 to 375 deg. Fahr. for from six to forty-eight hours, depending upon the class of material being treated.

FABRIC BEARING

By far the largest portion of rubber scrap comes under this class. Such material on arrival at the shoddy plant is sorted. All metal parts are removed. Where profitable, the outer layer of rubber is cut off. Thus auto tire treads and often the sides are skived (cut away) and placed in class I under auto tire peelings. Auto tire beads are also removed and placed in class III.

Following sorting, all material is ground finely by means of rapidly rotating knives. It is next screened and passed under the magnetic separator. This consists usually of a series of electro-magnets having a small belt passing across the pole face at right angles to the belt conveyor which carries the ground scrap. Any particles of iron or steel are drawn up and thrown to one side.

The separation of the fabric from the rubber compound is accomplished by various processes, which will be discussed under the following heads:

I. Mechanical.
II. Acid.
III. Alkali.
IV. Solution.

Mechanical Process.—This method is now little used. It consisted of blowing out the fluff by means of a regulated blast of air. It was a forerunner of modern air separation or grading. In this instance it proved a failure, since the fluff was never entirely free from rubber and vice versa. Consequently the separation was very incomplete.

Acid Process.—The first attempts at chemical separation were made along this line. The original process consists of heating the ground scrap with dilute sulphuric acid in steam jacketed kettles. An acid concentration of 3 to 5 per cent is used. The run lasts from 10 to 24 hr. at 320 to 340 deg. Fahr., depending upon the kind of scrap. Stirring devices are customary.

A clever modification of this process is that of W. A. Köneman, U. S. Pat. 823,053, Oct. 9, 1905. He uses hydrochloric or sulphuric acid, 5 to 10 per cent, and common salt in amount one-third of the weight of fiber and sulphur of the stock under treatment. He boils the mixture in an open vat by means of steam coils one hour at 220 deg. Fahr. without stirring. This process yields a very good product since the nerve of the rubber is not greatly attacked, due to the short time and low temperature of exposure to the acid. This has a decided advantage over the use of sulphuric acid alone, which tends to char the rubber hydrocarbon.

Another ingenious modification of the acid process consists in the substitution of zinc or magnesium chlorides for the sulphuric acid. Terry, English Pat. 11,482 (1911). Either of these supplies sufficient acid by hydrolysis.

Those processes using free acid besides hydrolyzing the cellulose to the water soluble form, also effect the removal to a more or less extent of the basic mineral fillers such as zinc oxide, lime, magnesia, etc. Sulphur in neither the free nor the combined state is in the least affected.

Following the acid treatment, the product must be well washed. The contents of the vat are usually worked over a riffler which is customarily about 300 ft. long and 2 to 6 ft. wide. the sides being a foot in height. This long chute is inclined, and has slats 2 to 4 in. in height spaced a foot apart. By means of a stream of water the vat liquor is washed away, and the rubber worked down the incline. At the bottom it goes into a settling box, where the floating stock is skimmed off. From here, the water used passes through a screen and into the sewer.

The wet stock is shoveled out of the settling box and further washed by passing it through corrugated washing rolls, just the same as in washing raw rubber. It is then taken to a centrifuge where most of the water is whirled out. It is further dried by exposing it in trays in a drying room.

The use of the riffler has been condemned by various rubber engineers as inefficient and wasteful. In fact, an adaptation of metallurgical washing methods to the problem would seem to me as beneficial.

The washing operation is of great importance in all shoddy processes, whether acid or alkali. Moreover, it is very difficult to remove the last trace of reagent, due to absorption by the rubber colloid. In acid processes this is not so dangerous, since washing will easily bring the acid content down to less than ½ of 1 per cent. By the addition of zinc oxide or other basic material to the finished product it may be neutralized. Unless this is done, the shoddy is liable to vary in rate of vulcanization, and in the case of incomplete washing it is liable, when 3 per cent acid is present, to be porous. In alkali processes absorption causes considerable trouble, since a small quantity of alkali, less than ½ of 1 per cent, acts as an unregulated accelerator, and the product is quite likely to harden on ageing. The presence of more than ½ per cent alkali retards vulcanization, and if 5 per cent is present it is impossible to cure the product within reasonable time.

The remedy is obviously some acid treatment using an acid which has no harmful effects on rubber. L. T. Petersen, U. S. Pat. 774,727, June 24, 1904, produces first an alkali shoddy and then heats it with carbolic acid. This gives an excellent solution of the problem since inactive sodium phenolate is formed and the excess carbolic acid acts as an antiseptic.

The shoddy at this stage—in the pans of the dry room—has but little cohesiveness. It is crumby, and must be depolymerized before it is fit for use. This is accomplished just as in treating fabric free material. However, tar is the chief material added. Varying percentages are mixed with the crumb, and the whole heated in contact with steam at around 300 deg. Fahr. for several hours, depending upon the kind of scrap being treated.

This heating, while quite necessary, has its disadvantages. As stated before, acid shoddy contains free sulphur, consequently long heating serves to further vulcanize the product, thus decreasing its value.

Alkali Processes.—Most of the shoddy manufactured in this country is made by the use of alkali. The first patent was granted to A. H. Marks, U. S. Pat. 635,141, Oct. 17, 1899. All other alkali patents are modifications of it. Marks accomplishes the removal of the fabric and depolymerization of the rubber at one heating. His process consists in submerging the finely ground rubber waste in a dilute alkaline (3 per cent sodium hydroxide recommended) solution in a sealed steam jacketed vessel, the contents of which are heated with stirring to a temperature of 344 deg. Fahr. (125 lb. of steam), which is maintained for twenty-four hours, more or less, as is necessary.

This is the gist of the most important patent in American shoddy practice, and is decidedly an advantage over the acid process. The finely ground waste is submerged in an inner vessel in 3 per cent alkali solution. This is sealed and steam at 125 lb. is turned into the container. The heat is continued with stirring as long as experience dictates, twenty to twenty-four hours is usual.

A modification of Marks' process is that by R. B. Price, U. S. Pat. 762,843, May 26, 1904. He treats finely ground waste with sodium hydroxide solution, boiling above the melting point of sulphur (232 deg. Fahr.). His solution may contain as much as 66 per cent NaOH. He claims that 1 lb. water and 1 to 2 lb. alkali per pound of rubber is about right. He boils the mixture at atmospheric pressure at 350 deg. Fahr., using a reflux condenser. In a previous patent, U. S. Pat. 693,151, April 11, 1901, he recommends the use of superheated steam (300 deg. Fahr. to 450 deg. Fahr.) for depolymerizing. A bath of 5 to 25 per cent sodium thiosulphate is given for the removal of free sulphur.

Probably a better modification of the Marks process is that of L. T. Petersen, U. S. Pat. 774,727, June 24, 1904. The finely ground scrap is treated in a heater differing but little from that of Marks, with a 10 to 15 per cent solution of alkali. This heat lasts but three hours, after which the stock is separated from the liquor which is likely used over again. It is washed and centrifuged, and then placed in a heater with a 1 to 10 per cent solution of phenol or similar hydrocarbon, such as cresol. The solution must be

weak enough to not dissolve any rubber. The heater for this step is similar to the one used for the alkali treatment. The steam pressure may be varied in the jacket from 50 to 175 lb. This heat lasts from six to forty-eight hours.

An electrolytic modification of the alkali process is that of C. S. Heller, U. S. Pat. 1,024,937, June 22, 1911. As an example of his process he cites a solution of 30 lb. alkali in 600 lb. water. To this are added 100 lb. of rubber waste and ½ lb. of ferric hydroxide. This solution is electrolyzed at a voltage of 0.4 to 0.6 volts and 700 to 1000 amperes. The temperature recommended is 360 deg. Fahr. The current is reversed twelve times per day. He claims to remove the sulphur.

Washing and drying are carried out much the same as in the acid process. Marks washes his product on a riffler and then through washing rolls. It is then fed wet through a hot mixing mill where it is dried and finally sheeted on the same set of rolls. These sheets are stored, ready for use or shipment. Depolymerized acid shoddy is also dried on hot rolls.

The advantages of the Marks process consist in removing, first, the free sulphur which unites with the alkali, forming sodium polysulphides; and second, all saponifiable material, such as rubber substitute, vegetable oils, etc. The process is very good, and the only objection is the slight trace of free alkali which cannot be removed. This defect is corrected by Petersen's patent, as before mentioned.

Below are some typical figures which will indicate the properties of the most important shoddies, namely, those from auto tires, boots and shoes, air brake and bicycle tires. These are alkali shoddies made by the Marks process. The physical tests were made on a vulcanized compound prepared as follows: 93 per cent shoddy, 4 per cent sulphur and 3 per cent lime. For sake of comparison, tests on Highlands Fine Para and Plantation Smoked Sheets are given. These compounds contained 90 per cent rubber, 1 per cent lime and 9 per cent sulphur.

Grade Shoddy	Rubber	Ash	Acetone Extract	Chloroform Extract	Total Sulphur, Per Cent	Specific Gravity	Tensile Strength, Lb. Sq. In.	Ultimate Elongation, Per Cent
Auto tire	56.54	40.00	9.48	14.13	3.46	1.40	815	450
Boots & shoes	46.35	50.15	8.25	17.55	3.50	1.60	800	210
Air brake	50.59	45.29	16.26	12.48	4.12	1.51	810	400
Bicycle tire	44.04	52.00	10.14	12.15	3.96	1.67	845	250
H. F. Para	90.00	....	*2.12	....	9.00	...	2,150	900
Smoked sheets	90.00	....	*3.33	....	9.00	...	1,970	950

*On the raw rubber.

Solution Methods.—Various solution methods have been proposed from time to time. The patent of P. Alexander, U. S. Pat. 821,394, Aug. 10, 1905, is the only one deserving serious attention. This process consists in the production of a colloidal emulsion of rubber in water. Any fabric or mineral fillers can be removed by filtration. He cites as an example of his process the following: 1000 Kg. of scrap are heated to 150 deg. C. with 3000 Kg. benzole for three to four hours in a closed vessel under pressure. Undissolved material is then mechanically removed. The solution is returned to the pressure vessel and heated to 150 deg. C. for about three hours with 200 Kg. sodium hydrate in 350 Kg. water. The solution is then steam distilled at low temperature to remove the benzole. The aqueous emulsion is filtered to remove mineral fillers. The rubber is precipitated by means of acid or combustion gases.

It is said that the process is inoperative. At least, there are some fundamental objections to its use. Experience with other rubber solvents has demonstrated that the combined sulphur would not be removed. Also, rubber precipitated from solution shows a marked diminution in tensile strength as compared with the original previous to solution.

Ebonite Waste.—Under this head comes all sorts of hard and semi-hard waste. The material when finely ground is termed dust and is so used in mixing.

A very ingenious method for the recovery of such waste is the patent of Thomas Gare, U. S. Pat. 967,751, Aug. 27, 1906. He subjects ground scrap to great pressure, one-half ton to the square inch, in a mold heated from 350 deg. Fahr. to 450 deg. Fahr. The combination of high temperature and pressure tends to soften and coalesce the dust so that molded articles closely resembling new goods are produced.

Attempts to Remove the Combined Sulphur.—Numerous patents have been granted for the removal of sulphur. The following is a list of the more important:

Inventor	Reagent	Patent	Date Granted
Theilgaard	Sodium sulphite	Eng. Pat. 10,821	1899
Dewer	Lime	Eng. Pat. 4,803	1901
Theilgaard	Sodium sulphide	Eng. Pat. 8,041	1899
Theilgaard	Cyanides	Eng. Pat. 10,822	1899
Bary	Metallic oxides	Eng. Pat. 7,153	1910

Bary and Weidert state that it is posible to remove the combined sulphur, and Hinrichsen and Kindscher, who examined the action of alcoholic soda and finely divided metals on both hot and cold vulcanized rubber came to the same conclusion.

Alexander differs with these men and claims that the sulphur they removed was only some residual free sulphur. This is extremely hard to extract, due to absorption. Prolonged treatment with hot acetone under pressure is necessary, and then it is a question if all the absorbed sulphur is removed.

To date it seems quite probable that the removal of the combined sulphur is likely to prove impossible. The difficulties are very great. Rubber is such a complex substance, and its affinity for sulphur is so strong that any reagent powerful enough to remove the combined sulphur would likely make the rubber unfit for commercial use.

It is the aim of modern civilization to prevent waste in whatever form it may occur. In rubber this prevention is only partially successful. It has been the aim of the writer to set forth the various important attempts so that the experimenter to come will not cover ground which has been gone over in the past. It is hoped that this paper will convey an impression of the difficulties in the way of a true solution of the problem, and also give us due respect for the service to society of those men who go through our streets calling "Old rags, rubber and old gum boots."

Franklin Institute Lectures

The following lectures are scheduled to be given before the Franklin Institute in Philadelphia during the next few weeks.

March 23—"Recent Developments in Electrical Apparatus," by Harold Pender.

March 30—"Some Problems in Physical Metallurgy at the Bureau of Standards," by George K. Burgess.

April 6—"Use of Powdered Coal in Metallurgical Processes," by C. J. Gadd.

April 13—"Heat Measurement as Related to the Industries," by Charles W. Waidner.

April 19—"Scientific Research in Relation to the Industries," by Charles P. Steinmetz.

Refrigeration in France*

BY L. MARCHIS

(*Concluded from page* 191)

III—Refrigerating Machines

1. CAPACITY AND PERFORMANCE

Mr. Marchis proposes the following definitions relating to the capacity and performance of refrigerating machines.

(a) *Interior Régime.* It is first necessary to consider, in the operation of refrigerating machines, the *interior régime* and the *exterior régime.*

The *interior régime* depends not only on the nature of the refrigerating fluid in use, but also on all the transformations of this fluid in the interior of the machine. It is difficult, not to say impossible, to define in any exact manner the various stages of these transformations. And for this reason, by analogy with the case of an ideal engine operating according to the Carnot cycle, we are led to characterize the internal régime of a compressor by means of the three following temperatures.

1. Temperature of vaporization of the refrigerating agent, corresponding to the pressure measured on the inlet gage.

T_v = Temperature, absolute.
t_v = Temperature, Centigrade.
$T_v = t_v + 273$.

2. Temperature of condensation of the refrigerating fluid, corresponding to the pressure measured at the exhaust gage.

T_c = Temperature, absolute.
t_c = Temperature, Centigrade.
$T_c = t_c + 273$.

When the refrigerating fluid operates at temperatures above the critical temperature, the serpentine of the liquefier plays the rôle of a cooler of the gas. For the latter, one can only define an average temperature, somewhat vaguely known. If by means of thermometers plunged into the gas, measures are taken, $t_c^{(1)}$ and $t_c^{(2)}$, of this gas at admission and discharge from the serpentine of the liquefier, we may take as the average temperature of the gas in the serpentine the mean value

$$t_c = \frac{t_c^{(1)} + t_c^{(2)}}{2}$$

3. Temperature of the refrigerating fluid on its arrival at the regulating valve, temperature measured by means of a thermometer plunged in the fluid.

T_r = Temperature, absolute.
t_r = Temperature, Centigrade.
$T_r = t_r + 273$.

This temperature is the lower, the better, the cooler for the liquid.

The difference between the two temperatures, $T_r - T_v$, characterizes the effect of the regulating valve.

4. Industrial experience shows that the values of the temperatures t_v, t_c, t_r, most commonly observed are the following:

$t_v = -10$ deg. C., $T_v = 263$ deg. absolute.
$t_c = +25$ deg. C., $T_c = 298$ deg. absolute.
$t_r = +15$ deg. C., $T_r = 288$ deg. absolute.

We propose to take these temperatures as suited to define the normal internal régime.

(b) *External Régime.* The study of the internal régime of the machine involves that of the transformations of the refrigerating fluid. That of the external régime concerns the interchanges of heat between the refrigerating fluid and the mobile media, that to be cooled about the evaporator, and that for cooling about the liquefier. The external régime is of more especial interest in the refrigerating industry. It permits, in effect, the standardization of the refrigerating action of the machine (useful effect) and of determining the expense of circulating water in the liquefier. The external régime may be characterized by the following temperatures:

1. Average temperature of the substance to be cooled in contact with the evaporator.

θ_v = temperature, Centigrade, corresponding to t_v.

If $\theta_v^{(1)}$ and $\theta_v^{(2)}$ are the temperatures of the substance to be cooled, before and after contact with the evaporator, we may take

$$\theta_v = \frac{\theta_v^{(1)} + \theta_v^{(2)}}{2}$$

2. Temperature of the condensing water at admission to the liquefier (whether or not the liquefier is provided with a cooler for the liquid).

θ_{ce} = temperature, Centigrade.

3. Temperature of the condensing water as it issues from the liquefier

θ_{cs} = temperature, Centigrade.

4. We propose to adopt, for the normal conditions of operation for the external régime, the following values of the temperatures:

For the cooling of brine:

$\theta_v = -5$ deg. C.
$\theta_v - t_v = 5$ deg. C.

In case of direct expansion

$\theta_v = 0$ deg. C.
$\theta_v - t_v = 10$ deg. C.
$\theta_{ce} = +12$ deg. C.
$\theta_{cs} = +20$ deg. C.

$$\frac{\theta_{ce} + \theta_{cs}}{2} = 16$$

$$t_c - \frac{\theta_{ce} + \theta_{cs}}{2} = 9$$

$$\frac{t_c + t_r}{2} - \frac{\theta_{ce} + \theta_{cs}}{2} = 4$$

(c) *Certain Definitions and Notations Relating to the Calculation of Compressors.*

1. Units of refrigeration produced in the evaporator per stroke of the piston = Q_v.

$$Q_v = Mr(T_v)$$

M = mass of refrigerating fluid circulating in the machine per stroke of the piston.
$r(T_v)$ = heat of vaporization of the refrigerating fluid at the temperature T_v.
$V = M\mathcal{v}(T_v)$ = volume swept by piston.
$\mathcal{v}(T_v)$ = specific volume of the saturated vapor of the refrigerating fluid at the temperature T_v.

We propose to give the name *Theoretical specific volumetric production* to the expression

$$P_{sv}^{(1)} = \frac{r(T_v)}{s(T_v)} \left(\frac{\text{units of refrigeration-kilograms}}{\text{met}^3} \right)$$

2. Theoretical indicated work per stroke of piston,

$$W_i = \frac{m}{m-1} P_v V \left[\left(\frac{P_c}{P_v} \right)^{\frac{m-1}{m}} - 1 \right]$$

where

P_c = pressure at the liquefier indicated by the corresponding gage.
P_v = pressure at the evaporator corresponding to the temperature T_v.

If the pressures are expressed in kilograms per square meter and the volumes in cubic meters, the work W_i is expressed in kg.-meters (if in pounds per square foot and cubic feet, work is expressed in foot-pounds).

*A paper read before the International Engineering Congress in San Francisco.

If the pressures are expressed in Newtons per square meter and the volumes in cubic meters the work W_i is expressed in Joules.

We propose to give the name *theoretical specific economic production* to the expression

$$P_{se}^{(t)} = \frac{P_{sv}^{(t)}}{\frac{W_i}{v}} \left(\frac{\text{units of refrigeration-kilogram}}{\text{kg.-meter or Joule}} \right)$$

If the work W_i is expressed in Joules and if $K_{wh}^{(t)}$ is the corresponding number of watt-hours, we have

$$K_{wh}^{(t)} = \frac{W_i}{36 \times 10^5}$$

$$P_{se}^{(t)} = \frac{1}{36 \times 10^5} \times \frac{P_{sv}^{(t)}}{\frac{K_{wh}^{(t)}}{V}}$$

Let us place

$$\Pi_{se}^{(t)} = 36 \times 10^5 P_{se}^{(t)}$$

We then have

$$\Pi_{se}^{(t)} = \frac{P_{sv}^{(t)}}{\frac{K_{wh}^{(t)}}{V}} \left(\frac{\text{units of refrigeration-kilogram}}{\text{kilowatt-hour}} \right)$$

The factor m which enters into the expression for W_i is not well known. The values commonly assumed are as follows:

NH_3 ..... $m = 1.32$
SO_2 ..... $m = 1.27$
CO_2 ..... $m = 1.30$

3. We propose to give the name *indicated thermal performance* to the abstract number

$$\rho_i = EP_{se}^{(t)} = 36 \times 10^5 \times \Pi_{se}$$

E being the mechanical equivalent of heat.

Where the unit of work is the Joule and the unit of mass is the kilogram, $E = 9.8 \times 425$.

4. The theoretical refrigerating power of a compressor per unit of volume swept by the piston or the *theoretical volumetric refrigerating power* may be represented by the notation

$$P_{fv}^{(t)} \left(\frac{\text{units of refrigeration-hour}}{\text{cubic meter}} \right)$$

If n is the number of revolutions per minute we have

For a single-acting machine: $P_{fv}^{(t)} = 60 \times n \times P_{sv}^{(t)}$

For a double-acting machine: $P_{fv}^{(t)} = 120 \times n \times P_{sv}^{(t)}$

5. The theoretical cooling power of the condenser per unit of volume swept by the piston, or *theoretical volumetric cooling power* may be represented by the notation

$$R_{cv}^{(t)} \frac{\text{kilogram calories}}{\text{cubic meter}}$$

In virtue of the principle of equivalence, it has for expression

$$R_{cv}^{(t)} = P_{sv}^{(t)} \left(1 + \frac{1}{E} \times \frac{I}{P_{se}^{(t)}} \right)$$

6. The theoretical consumption of water at the condenser per unit volume swept by the piston or *theoretical volumetric consumption of water* is

$$\Delta_{ev}^{(t)} = \frac{\text{kilogram}}{\text{cubic meter}}$$

It has for value the expression

$$\Delta_{ev}^{(t)} = \frac{R_{cv}^{(t)}}{\theta_{cs} - \theta_{ce}}$$

The theoretical calculation of a compressor is then based on the knowledge of $P_{sv}^{(t)}$ and of $P_{se}^{(t)}$

(d) ***Certain Definitions and Notations Relative to Compressors in Industrial Operation.***

1. We propose to give the name *practical specific volumetric production* to the quotient:

$$\frac{\text{kilogram frigories}}{\text{cubic meter}} P_{sv}^{(p)} = \frac{\text{Units of refrigeration produced in the evaporator by the vaporation of the refrigerating fluid.}}{\text{Volume in cubic meters actually swept by the piston.}}$$

If, as is usually done, we measure the units of refrigeration produced in the evaporator by the cooling of the external medium, this method assumes that the *efficiency of the evaporator* (ratio of the units of refrigeration actually produced in the evaporator to the units measured by determining the cooling of the external medium) is very near unity; that is, that the evaporator is well filled with refrigerating fluid.

If this method of procedure is not followed, it is necessary to measure the mass of fluid circulating in the machine during a determined time, and this is very difficult to realize to a sufficiently accurate degree.

The *practical volumetric refrigerating power,*

$$P_{fv}^{(p)} \frac{\text{units of refrigeration-hour}}{\text{cubic meter}}$$

has for value the expression:

For a single-acting machine

$$P_{fv}^{(p)} = 60 \times n \times P_{sv}^{(p)}$$

For a double-acting machine

$$P_{fv}^{(p)} = 120 \times n \times P_{sv}^{(p)}$$

These expressions assume that $P_{sv}^{(p)}$ corresponds to one stroke of the piston.

2. We propose to give the name *volumetric efficiency* of a compressor to the ratio

$$\rho_v = \frac{P_{sv}^{(p)}}{P_{sv}^{(t)}}$$

As the number of units of refrigeration really produced in the evaporator has for value the expression $Mr(T_v)$, this efficiency is also equal to the ratio of the actual to the theoretical volume of the compressor.

3. We propose to give the name *practical specific economic production* (related to the indicated kilowatt-hours) to the ratio

$$\Pi_{se}^{(p)} = \frac{\text{Units of refrigeration produced in the evaporator by the vaporization of the refrigerating fluid.}}{\text{Number of indicated kilowatt-hours furnished to the compressor.}}$$

This definition must be completed by an indication of the mechanical efficiency of the compressor, ρm or ratio of the number of kilowatt-hours actually delivered on the compressor shaft to the number furnished to it.

The practical specific economic production (related to the kilowatt-hours expended on the compressor shaft) has for value the expression:

$$\Pi_{se}^{(p)} \times \rho m$$

4. We propose to give the name *economic efficiency* of the compressor to the ratio:

$$\rho_e = \frac{\Pi_{se}^{(p)}}{\Pi_{se}^{(t)}}$$

This number measures also the ratio of the indicated kilowatt-hours actually furnished to the compressor to the theoretical indicated kilowatt-hours.

5. The *practical volumetric refrigerating power* of the liquefier is

$$R_{cv}^{(p)} = P_{sv}^{(p)} \left(1 + \frac{36 \times 10^5}{E} \times \frac{1}{\Pi_{se}^{(p)}} \right)$$

When $E = 9.8 \times 425$

$$R_{cv}^{(p)} = P_{sv}^{(p)} \left(1 + 863.3 \frac{1}{\Pi_{se}^{(p)}} \right)$$

6. The *practical volumetric consumption of water* is

$$\Delta_{ev}{}^{(p)} = \frac{R_{ev}{}^{(p)}}{\theta_{cs} - \theta_{ce}}$$

(e) *The Construction of Refrigeration Machines in France.*

As is shown by the statistical table annexed hereto, the refrigerating capacity of the machines in operation in France attains, for fixed installations, at least 74,000,000 frigories per hour (units of refrigeration). A great number of these machines are built in France—at least 60 per cent of the preceding capacity.

If we consider the nature of the refrigerating fluid, the machines built in France fall into five types:

(1) Ammonia.
(2) Sulphur dioxide.
(3) Carbon dioxide.
(4) Methyl chloride.
(5) Water under partial vacuum.

The first four classes of machine are of the so-called *compression* type. Machines of the absorption type are no longer built in France. There are only a few now in operation in ice plants.

Methyl chloride is only used in the Douane machines; this medium is moreover not employed in other countries.

Furthermore, the type using water under partial vacuum is peculiar to the Westinghouse Company, which builds it under the direction of its inventor, Mr. Maurice Leblanc. We shall refer to this machine at a later point.

The ammonia machine is built especially by:

(1) The Société des Moteurs à Gaz et d'Industrie Mécanique (formerly Fixary).

(2) The Société Delaunay-Belleville.

The compressors of the first company are developed from the Linde type. They realize the greatest refrigerating capacities at present obtained. Thus, for example, this company has now under construction, for use in connection with the driving of mine shafts, compressors for 330,000 units of refrigeration (165,000 units per cylinder) formed of two cylinders opposed and mounted on the same foundation.

The Delaunay-Belleville Company builds compressors with flat bed-plate and with valves placed at the sides (axes of valves normal to axis of cylinders).

These compressors, double-acting, operate at rotative speeds not exceeding 150 r.p.m.

Recently a single-acting compressor under the name "equator" has been proposed, with a rotative speed of 500 r.p.m. At a certain point in the stroke the piston uncovers certain openings by which enter the gases coming from the evaporator. As to the exhaust valves, they are formed of simple bars of steel placed over the openings connecting with the condenser. This compressor, still under test, has given good results.

Machines operating with sulphur dioxide are more numerous than those with ammonia, but their total refrigerating capacity is less than that of the ammonia machines.

The Pictet Company is one of the oldest houses building machines operating with sulphur dioxide. The present type shows a cylinder with jacket for water circulation and a double stuffing-box for the circulation of water, which assures the cooling of the piston rod. In order to realize high rotative speeds (up to 300 r.p.m.), use is made of valves formed of a light disk held at the center.

The house Lepeu also builds machines operating with sulphur dioxide, with very light disk valves for high rotative speeds.

A type of compressor altogether peculiar to France is the Audiffren-Singrün. It has neither stuffing-box nor valves. The compressor is imprisoned in a hermetically sealed inclosure, on the interior of which acts the pressure of the liquefier. The compressor may be operated by an external motor without piercing the wall of the space which contains it, that is to say, without employing a stuffing-box. To this end it is sufficient to revolve the closed compartment containing the compressor. The mechanism of the latter, to which is given an alternating movement, is maintained fixed in space by means of a mass of lead of sufficient weight, which ballasts the shell containing the pump of the compressor. This machine is especially used for the manufacture of ice in small quantities for domestic use, yielding 3 to 4 kg. (6.6 to 8.8 lb.) per hour. For such purpose it is furthermore very practical, for it requires no supervision and can be put into operation by any domestic. However, larger machines are now in hand, capable of making 50 and 100 kg. (110 and 220 lb.) of ice per hour. We shall refer at a later point to a traveling installation in which this type of compressor has yielded the best of results.

The house Dyle and Bacalan builds compressors operating with carbon dioxide, of the English type "Hall." This house has more particularly specialized in the construction of machines for small dairies and for marine uses.

The Froid Industrial Company also builds machines using carbon dioxide for marine service.

Mr. Maurice Leblanc of the Westinghouse Company, has brought into service a machine in which water is used as the refrigerating fluid. It produces the cooling of brine by inducing its evaporation under a suitable reduction of pressure. This partial vacuum is realized by means of a jet of vapor, which, issuing at high speed from an orifice surrounded by a suitable diffuser, entrains large quantities of water vapor.

However, in order to obtain in the evaporator a temperature of the brine sufficiently low, that is a sufficiently low tension of the vapor emitted by the solution, it is necessary to realize at the condenser of the vapor a very low pressure. This is realized by the use of an *ejector-condenser*, that is, a condenser in which the vacuum pump is constituted by a liquid ejector.

This machine presents the advantage of having neither poppet valves nor check valves subject to rapid wear. It is also very silent.

An important saving is realized by the use in the vapor ejectors of exhaust vapor from other vapor motors, as turbines for example. Thus at the refrigerating abattoir at Chasseneuil (Poitou), the exhaust from a steam turbine under a pressure of 2 kg. per sq. cm. (28.4 lb. per sq. in.) passes into the ejectors and produces in the evaporator a vacuum of 2 mm. (0.08 in.) of mercury.

The efficiency of an ejector machine is the ratio of the number of units of refrigeration produced in the evaporator to the number of heat units absorbed by the refrigerating water in the condenser. If consideration is given to the temperatures corresponding to the tensions of the vapor of water in the evaporator and the condenser, the efficiency diminishes rapidly when the difference of these temperatures increases. It has a value about 30 per cent for a difference of temperature equal to 15 deg. or 20 deg. C., that is, a temperature of 5 deg. to 0 deg. C. in the evaporator for a temperature of + 20 deg. C. in the condenser.

For this reason, the ejector machine is well suited to use in all cases where it is not necessary to push the refrigerating effect below 0 deg. C. Such is the case in chemical and pharmaceutical industries. The largest installation of this type has a machine of 1,050,000 frigories per hour (units of refrigeration) with a temperature of the brine on entering the evaporator = + 26 deg. C. and on leaving the evaporator = + 19 deg. C.

This machine was installed at the plant of M. Gillet at Lyon-Serin for cooling bichloride of tin, used in the process of dyeing black silk.

But it is on shipboard that ejector machines may find their most significant field of use. They employ a refrigerating fluid which involves no danger of fire and which can be renewed with sea water. Likewise, ejector machines serving to cool to a few degrees below 0 deg. C the air circulating in ammunition rooms have been installed on a large number of French battleships, and even on Russian and Austrian ships of the same type. Machines of this type have also been employed for the refrigeration of food stores for passengers on four steamers of the French merchant marine. The total number of machines installed on shipboard is fifty-eight, with an aggregate refrigerating capacity of 2,000,000 frigorie-hours (units of refrigeration).

The ejector machine presents the serious drawback of requiring at the condenser a considerable amount of cooling water.

On this account, for stationary installations, Mr. Leblanc has undertaken the construction of a pump mechanically operated, and capable, with a small volume, of aspirating the enormous volumes of water vapor required by the use of this substance as the refrigerating fluid. To this end he has turned to the rotative type of pump.

But the problem presents serious difficulties. The rotary compressor must be of small dimensions, it must require only a small power for operation and must, nevertheless, be capable of aspirating several cubic meters per second of a vapor of density much less than that of air. But, the less the density of the aspirated air, the greater must be the peripheral velocity of the vanes; the more the power absorbed by the compressor is reduced, the more must the angular velocity be increased.

Suppose that we have such a turbo-compressor formed of four rings of vanes of decreasing diameter in series, of which the largest has a diameter of 320 mm. (12.6 in.). The peripheral speed which the large wheel must realize being 500 meters (1640.4 ft.) per sec., the rotor must turn at a speed of 30,000 r.p.m. A mass weighing 1 gram. (0.0022 lb.) placed on the periphery of the large wheel would be subject to a centrifugal force of 160 kg. (352 lb.).

In order to construct vanes able to resist forces of this magnitude, while at the same time sufficiently light, Mr. Leblanc has employed threads of ramie stretched parallel and consolidated by dissolved cellulose.

It is further necessary that the shaft and the rings of fiber vanes (constituting the rotor) be balanced in such manner that the axis of figure shall coincide with the principal axis of inertia. Mr. Leblanc has achieved this by the use of automatic equilibrators constituted by the use of hollow tori partially filled with mercury. Further the rotor is carried on very light bearings, themselves resting on springs very supple and of small mass.

A compressor of this type is still under experimental development. So far as known, it has not yet been introduced into practical use.

IV.—APPLICATIONS OF REFRIGERATION

1.—THE TRAVELING REFRIGERATING PLANT OF THE FRENCH ASSOCIATION DU FROID

The French Association du Froid has developed the plan of a traveling refrigerating plant in order to demonstrate on the spot to agriculturists the advantages which may be realized by the use of refrigeration. To this end it has built, with the aid of various French manufacturers, a special car constituting a veritable traveling refrigerating plant, which it proposes to locate, for the time, in various regions of France.

This car is divided, by transverse partitions, into three compartments. In the center a room for the machinery and at each end a refrigerator room.

The room for the machinery is 2.48 m. for 2.39 m. by 2.28 m. high (8.15 ft. by 7.85 ft. by 7.5 ft. high) at the center, and 1.96 m. (6.4 ft.) high at the sides. Ventilation is assured by means of the door placed at the center of the car, and by a movable shutter in the wall opposite the door.

The two cold rooms are of different dimensions. One, called the refrigerator room, measures 2.25 m. by 2.27 m. (7.35 ft. by 7.45 ft.); the other, called the freezing room, measures 2 m. by 2.27 m. (6.56 ft. by 7.45 ft.). Both have a height of 1.8 m. (5.9 ft.). Access to these rooms is obtained by way of two doors constructed in the partition opposite to that in which is located the door of the machinery room.

The refrigerating machine is of the Audiffern-Singrün type, with a capacity of 1500 frigories per hour. It is driven by an explosion motor of 4 hp. running at 400 r.p.m. and using benzol as fuel. The tank of brine in which is plunged the refrigerating shell of the machine is provided with a distributing header. The circulation of the brine is furthermore realized by means of a pump.

The insulation of all the walls of the car has been made with especial care. It has been planned with a view of reducing the loss of heat to an amount not exceeding 0.5 carlorie per square meter per hour (0.184 B.t.u. per sq. ft. per hr.).

This insulation is made up as follows:

Outer walls of car—from interior to exterior.

Wood	15 mm. (0.59 in.)
One thickness of insulating paper	
Wood	15 mm. (0.59 in.)
One thickness of insulating paper	
Cork in sheets	40 mm. (1.58 in.)
Wood	25 mm. (0.99 in.)
Cork in sheets	50 mm. (1.97 in.)
One thickness of insulating paper	
Cork in sheets	50 mm. (1.97 in.)
One thickness of paper and wood	20 mm. (0.79 in.)

Partitions separating the refrigerator rooms from the machinery room.

Wood	15 mm. (0.59 in.)
One thickness of insulating paper	
Cork in sheets	120 mm. (4.73 in.)
One thickness of insulating paper	
Wood	15 mm. (0.59 in.)

Floor—from interior to exterior.

Two thicknesses of boards of 20 mm., each laid with broken joints	40 mm. (1.58 in.)
One thickness of insulating paper	
Cork in sheets	100 mm. (3.94 in.)
One thickness of insulating paper	
Wood	20 mm. (0.79 in.)

Ceiling of car.

Wood	25 mm. (0.99 in.)
Covering on inside	
Cork	100 mm. (3.94 in.)
One layer of insulating paper	
Wood	20 mm. (0.79 in.)
Covering on outside	
Cork	50 mm. (1.97 in.)
Wood	15 mm. (0.59 in.)
One thickness of felt	
One layer sheeting soaked in bitumen.	

The cooling of each of the two rooms may be effected either by the circulation of brine, or by the circulation of cold air, or by both methods together. It is, in fact, necessary to make, between — 10 deg. C. and + 10 deg. C., the various demonstrations regarding the products which may be preserved by refrigeration—such as meat, fish, fruit, flowers, vegetables, butter, eggs, etc.

The brine (solution of chloride of calcium) is sent into holders, three of which are placed in each room. Each of these is made up of nine tubes of 10 cm. (0.394 in.) diam. and 1.60 m. (63 in.) long. There is therefore in each refrigerator room about 350 liters (92.4 gal.) of brine.

Furthermore, in the upper part of each room is arranged a space 36 cm. (14.2 in.) high by 1.6 m. (63 in.)

wide separated from the rest of the room by a partition composed of two thicknesses of board with 60 mm. (2.36 in.) of sheet cork between them. This space contains the refrigerator coils. The air is sent over these refrigerating coils through an exhaust conduit, circulates in the refrigerator room and is drawn out through other conduits by means of the ventilator. The air conduits which traverse the machinery room are made of two thicknesses of wood separated by a layer of insulating paper.

All piping which carries brine to the containers and to the refrigerating coils is insulated with consolidated cork chips 40 mm. (1.58 in.) in thickness.

Experiments were commenced with this traveling plant, but unfortunately they have been interrupted by the war. Nevertheless, the results thus far obtaind show that this manner of demonstration will, in the future, be of great service.

2.—REFRIGERATION IN THE WINE INDUSTRY

Among the applications of refrigeration, one which, in France, in recent years, has attracted especially the attention of savants, is the treatment of wines by low temperatures.

The second French Congress of Refrigeration, held at Toulouse in September, 1912, at the suggestion of the French Society of Refrigerating Engineers, decided on the formation of a sub-committee on the applications of refrigeration in the wine industry. It is charged with the duty of grouping, in the principal grape-growing regions of France, chemists, proprietors, dealers and growers who might be disposed to interest themselves in the various applications of refrigeration for the treatment of musts, of wines, brandies, liqueurs, ciders and aperitifs with a wine base.

Even before the constitution of this sub-committee, reports on various important investigations regarding this question had been published by Dr. Carles of Bordeaux, and by Mr. Mathieu, director of the Oenological Station of Bourgoyne. The purpose of the new committee was to group the results of these various investigators and to give definite scientific indications regarding the effects of refrigeration in the wine industry.

The Committee of the South West installed at Bordeaux, has already made known a certain number of results which we give here in résumé.

It has long been known that, subjected in winter to the prolonged action of cold (without going to congelation), new wine undergoes more rapidly a spontaneous normal purification. This effects a number of constituents such as the least stable part of the color, the nitrogeneous and mucilaginous matters, organic and mineral salts. It is known also that the precipitation of cream of tartar forms the most important of the deposits, and that it produces a corresponding reduction in the acid content which, joined to the loss of the tannoïdal substances, results in a diminution of the rough taste of new wines. To this improvement in the taste must be added the arrest of ferments due to anaerobic bacteria which are almost always present in new wines, an arrest which favors their ulterior elimination and, in consequence, the normal preservation of the wine.

Nature of Installation	Total No. of Installations	Installations with Ammonia Machines: No.	Ammonia Machines: Capacity in Frigories per Hour	Installations with Sulphur Dioxide Machines: No.	Sulphur Dioxide Machines: Capacity in Frigories per Hour	Installations with Carbon Dioxide Machines: No.	Carbon Dioxide Machines: Capacity in Frigories per Hour	Installations with Methyl Chloride Machines: No.	Methyl Chloride Machines: Capacity in Frigories per Hour	Installations with Water Under Vacuum: No.	Water Under Vacuum: Capacity in Frigories per Hour	Total Refrigerating Power in Frigories per Hour	Remarks
I. Abattoirs	32	19	1,950,000	9	50,000	1	8,000	2	124,000	1	150,000	2,282,000	57 machines
II. Wholesale grocers	49	32	764,000	8	172,000	6		3	34,100			970,100 minimum	48 machines for 42 install.
III. Meat shops	116	40	216,880	57	142,100	14		6				358,980 minimum	91 machines for 91 install.
IV. Breweries	445	118	7,851,500	262	8,741,500	63	4,260,000	2				20,853,000 minimum	
V. Pork packers and cooked meats	58	15	444,000	31	375,000	10		2				819,000 minimum	
VI. Chocolate shops	77	46	518,000	19	139,000	7	70,000	5				727,000 minimum	
VII. Confectioners and pastry shops	15	5	34,500	9	12,600	1						47,100 minimum	
VIII. Distilleries	9	4	380,000	4	41,000			1				421,000 minimum	
IX. Cold storage establishments	124	40 min.	3,039,100	34 min.	126,700	16 min.	316,000	5 min.				3,481,000 minimum	
X. Storage vaults for wine and beer	8	2	23,000	4	240,000 for 2 install.			2				263,000 minimum	9 machines
XI. Ice plants (domestic use)	686	194	11,462,000	276	2,257,000	59	1,193,000	156		1	4,000	14,916,000	
XII. Ventilation of mine shafts	9	9	20,400,000									20,400,000	77 machines
XIII. Cheese factories	38	30	1,029,000	6	60,000 about			2	2,000 about			1,091,000	
XIV. Cold storage of fruit	8	3	112,000	4	6,800			1				118,800 minimum	
XV. Hotels, taverns, restaurants	67	11	87,000	29	145,000 min.	14	15,000 min.	12	10,000 min.			257,000	1 install. with air expansion machine
XVI. Chemical and pharmaceutical industries	142	57	2,593,000	19	326,000 min.	21	566,000 min.	38	89,000 min.	7	1,192,500	4,766,500 minimum	160 machines
XVII. Horticultural establishments	3			3	18,500							18,500	
XVIII. Laboratories	38	4 min.		20 min.		min.		2 min.					
XIX. Milk and cheese industries	187	30	541,000	40	231,000	71	682,500	46				1,454,500	152 machines
XX. Morgues	7	4	90,400			1	15,000	2	36,000			141,400	
XXI. Sanatoria	11	1	3,000	9	17,100			1				20,100	
XXII. Wine and liquor industries	27	5	115,500	11	132,600	2	92,000	9				340,100	26 machines minimum
Total	2156	669 min. 31.2%	51,653,880 min. 70.0%	854 min. 39.9%	13,233,900 min. 18.0% about	289 min. 13.5%	7,217,500 min. 9.8%	297 min. 13.6%	295,100 min. 0.4%	9 0.4%	1,346,500 1.8%	73,746,080 minimum	

Marine and Railway

I. Ammunition rooms	28					7	540,000			21 for 58 machines	1,912,000	2,452,000	
II. Refrigerating ships	82												
III. Refrigerating cars	360 about												

In short, wine subjected to cold is refined more rapidly and may, in consequence, be presented to the trade after a shorter period of ripening.

Those results of the action of cold were, until quite recently, empirical. There had been scarcely any systematic attempt to scientifically study their production and control.

The experiments made by the Bordeaux Committee, although limited to a small number of wines, enable us to say that the principal advantages attributed to natural cold may also be realized by means of artificial refrigeration.

The application has been made in two ways.

1. *Rapid Refrigeration and Short Period of Application of Cold.*

The wine is rapidly cooled to a temperature of — 5 deg. C., first in a receptacle cooled by wine already cold, then by circulation around a serpentine filled with a refrigerating fluid. This cold wine remains then about a week in vats of 50 hectoliters (1320.8 gal.) insulated thermally and cooled inside by a coil carrying a current of refrigerating fluid.

2. *Slow and Prolonged Refrigeration in Rooms Kept at Temperatures About 0 Deg. C. and — 3 Deg. C.*

Casks are introduced into the cold rooms in a storehouse and left there during a considerable time (in the actual case about four months).

The results obtained by these methods indicate that the treatment by rapid refrigeration gives less favorable results than the prolonged treatment does in cold rooms.

However, the treatment lasting four months constitutes scarcely an economic treatment. Further experiments should be undertaken in order to see if the maximum effect may not be obtained at the end of shorter period of time. Furthermore, the present experiments have not made it possible to discriminate between the temperature 0 deg. C. and — 3 deg. C.

Further experiments should be made to elucidate this new question.

Paris, France.

Pure and Applied Chemistry.—In a paper presented before the Second Pan-American Congress in Washington, Dr. F. W. CLARKE pointed out that the earliest chemical data were obtained empirically, mostly by accident, and in the slow development of the arts. As such data accumulated, men began to reason about them, chemical doctrines were evolved, which, however, had little or no real validity. The atomic speculations of the Greeks were unfruitful, and led to no real advance. The atomic theory of Dalton was different. It was quantitative, it correlated known relations, and founded our present system of chemical formulas, chemical equations, and chemical arithmetic. From those additions to our knowledge chemical industries have derived much profit. The theory of valency and the benzene ring of Kekulé were outgrowths of Dalton's discoveries, and have guided practically all of the researches into coal-tar chemistry, with its dyes, medicines, and explosives. This union of theory and practice is characteristic of scientific chemistry. Between pure and applied chemistry the difference is one of purpose, of motive. The search for truth itself on one side, the utilization of the truth on the other. Discovery, however, must precede use. On the other hand, applied science stimulates research and each aids the other. Endowed laboratories should be established, in which corps of trained men should work together on problems that are too great for individuals to handle. Co-operation among chemists is needed in order that science may grow more symmetrically and systematically.

The Recovery of Wool Fat

BY EUGENE E. AYRES, JR.

It is estimated that in the vicinity of Philadelphia alone from five to ten thousand pounds of wool fat are being thrown away every day of the year. The recovery of this fat is becoming more and more important to wool scourers for several reasons, the chief of which is the abnormally high price of a reasonably good product. The purified fat, "lanolin," has hitherto been imported from Germany, as the market in this country has never been very great, but the partially purified "neutral wool fat" has always been in great demand.

The wool scouring plants in the thickly populated countries of Europe are compelled by rigorous legislation to remove all grease from their scouring waters, and they have succeeded in developing quite an adequate market. Germany and France produce a relatively enormous amount of wool fat, and have been disposing of it in various ways. Some is subjected to a purification process, by which all odor and nearly all color is removed. This product is put up either in anhydrous form or in thick emulsions as a toilet preparation, for "lanolin" is known to be exceptionally beneficial in its action on the skin. The general market for the commercial "neutral wool fat" is well known. Some of the cruder fat is converted by destructive distillation to an illuminant, "Fettgas." Some of the wool fat is distilled under pressure to obtain a pure white paraffine-like substance, the utilization of which is not generally understood in this country. Our personal acquaintance with the demand for wool fat is not specific but general. We have been in touch with many industries who are very anxious to get hold of comparatively large amounts.

The literature on wool fat is confusing, for each investigator has worked with samples that were obtained by different methods of scouring, recovery, and purification. Moreover, the fat will always vary in composition according to the source. The fat content, as determined by gasoline extraction of various wools, will vary from 5 to 25 per cent, depending on the breed and health of sheep, locality, and treatment before shearing.

Broadly speaking, less than 1 per cent of neutral wool fat is saponifiable under ordinary conditions. The crude fat as it comes from the wool contains some lower fatty acids already saponified by the action of soda ash in the scouring water and also some fatty acids (from acetic to caproic) that result partly from fermentation, and partly from the action of heat in breaking down some of the more complex esters. As the scouring waters are alive with bacteria, it is well to keep the temperature high enough to prevent fermentation, but not so high as to decompose the fat.

It is plain that the recovery of wool fat involves not only a separation from the scouring water, but also from soaps and the lower saponifiable fatty acids.

Wool fat is very soluble in all ordinary organic solvents, except ethyl and methyl alcohol. At 20 deg. C. ethyl alcohol dissolves about 0.5 per cent. The solubility in methyl alcohol is much less. The relative insolubility of wool fat in alcohol has been used as a means of purifying from fatty acids, but unless a powerful centrifuge is used, the treatment is possible only when no soaps are present, for a trace of soap will cause a very complete emulsion.

There are two processes for wool scouring. One, which is little used in this country, involves a gasoline extraction of the wool fat. The solvent is distilled off and the product, containing all impurities, is sold as "de gras." The more common procedure is to wash with a weak aqueous solution of soap, soda ash, and am-

monia. The wash waters contain the wool fat emulsified and soapy impurities in solution. The wool fat may be recovered simply by maintaining a temperature of about 140 deg. Fahr. The fat from some sources will separate over night, but usually several weeks will be required. A study of this severe emulsification brought out the fact that it is caused by the presence of the soap in conjunction with certain unidentified impurities in the wool fat. Pure lanolin will not emulsify to any great extent with these weak soap solutions.

The wool fat can be separated by precipitating all soaps by the addition of lime or of calcium chloride, but the recovery of fat from calcium soaps is a rather expensive extraction proposition. The wool fat can also be separated by precipitating the fatty acids with hydrochloric or sulphuric acids. The fatty acids, which are highly soluble in wool fat, are exceedingly difficult to remove, and can be neutralized only in alcoholic or aqueous solution, with formation of a soap emulsion.

The most natural process must, of course, be found in the proper application of centrifugal force. No better wool fat can be prepared than by successive gravity separations in the laboratory, but gravity is too slow. Recently, considerable work has been done on the commercial recovery of wool fat by centrifugal force. The selection of the proper type of machine was the essential factor. The qualifications were these: the delivery of melted fat must be continuous; the separation must be equally efficient for any percentage of fat; the separation must be efficient for the lowest temperature possible. By the courtesy of the Sharples Specialty Company a continuous centrifuge was provided that fulfilled all these conditions. It was found that a scouring water containing 1.55 per cent of wool fat yielded 1.45 per cent, each machine yielding from 10 to 11 lb. of fat an hour. The temperature was 140 deg. Fahr. The product was light yellow, contained little water and offered fewer purification difficulties than the fat from any other recovery. It developed that by increasing the volume of scouring water the efficiency of separation was considerably reduced, and that by decreasing the volume, the efficiency was not improved. A number of scouring waters from different sources gave somewhat different figures, but the figures above should be fairly representative.

The purification of wool fat can be effected by a combination of washing and chemical bleaching agents. The elimination of odor depends not on the actual removal of the odoriferous substances, such as butyric or caproic acids, but on their oxidation, reduction, condensation, or hydrolysis. Large volumes of water will effect hydrolysis to a certain extent. Here again a centrifuge is indispensable. Dilute sulphuric acid will improve the odor to a marked degree, possibly by condensation of the odoriferous components, but the fat will be darkened.

Of all the bleaching agents tried, sulphur dioxide appears to give the best results when properly applied. Chlorine, in nascent condition, has also been successfully used.

In view of the generally awakened interest in the recovery of by-products, our experiments should prove of some interest. If it should ever be desired to completely purify our scouring waters, 90 per cent or more of the fat can be removed in nearly pure form, and the other 10 per cent can be precipitated and discarded with impurities by adding a trace of acid and passing through a proper type of centrifugal. The profit from such an operation would be far in excess of the costs, whereas a recovery by precipitation can never be made to pay for the expense of equipment and operation.

West Chester, Pa.

The Raw Materials of the Blast Furnace

BY J. E. JOHNSON, JR.

The raw materials for the production of iron are three, the ore, the fuel, and the flux. Fuels have already been described in the introductory article of this serial and flux has received all the discussion necessary in the article on chemical principles. We have, therefore, only to deal with ores which, as already explained differ in the case of iron from those of any other metal in that they are exclusively the oxides.

Oxides of iron found in nature are three in number, ferric oxide Fe_2O_3, hydrated ferric oxide $Fe_2O_3 + H_2O$, and ferric ferrous oxide Fe_3O_4, commonly known as magnetic oxide or magnetite.

There is a fourth oxide, ferrous oxide FeO, but it does not occur in nature under ordinary conditions for the reason that when produced it instantly absorbs oxygen from the air or any other source and converts itself to ferric oxide Fe_2O_3.

It is a matter of much geological importance as affecting the origin and cause of iron ore deposits that iron in the ferrous condition is soluble in water containing carbonic acid and in dilute solutions of vegetable acids.

The only ferrous condition in which we ordinarily find iron is as the carbonate. This occurs in nature in great quantities. Its solubility in water containing carbonic acid is not so great as that of limestone, and when an iron-bearing solution meets a body of limestone the iron is deposited and the more soluble limestone removed.

It is probable that an action of this general nature has been responsible for the existence of a large percentage of those iron concentrations in nature which are commercially known as ore deposits; though in most of such cases the iron has undergone a process of subsequent oxidation which has left the iron as ferric oxide sometimes hydrated and sometimes not.

There are no deposits of carbonate of iron in the United States now being worked on a commercial scale, though in the Lake Superior region there are vast deposits of lean carbonate which may eventually, by concentration or otherwise, come into commercial use.

There are, however, very large deposits of iron carbonate on the Canadian side of Lake Superior which promise to become of much commercial importance to the iron industry of Canada. These ores are unusually high in manganese and quite high in sulphur. It is necessary to eliminate both the sulphur and the carbon dioxide, the latter because its weight is about 30 per cent of the total so that the freight is correspondingly reduced by its removal, and because the coke solution loss caused by the liberation of this carbon dioxide in the furnace would be ruinous.

The removal of both objectionable components is effected by roasting and the resulting product contains over 50 per cent iron and unusually low phosphorus about 0.010 per cent.

The gangue of the ore consists very largely of lime and magnesia, so it is more than self-fluxing, which is a great advantage, while its physical condition is excellent as it is crushed to small lumps almost free from fines, and retains that condition after roasting.

The black-band iron ores which occur in some coal fields and which were formerly successfully worked in western Pennsylvania are impure carbonates, but these are no longer in commercial use, having been superseded by richer and cheaper ores. In Europe, in England especially, there are great bodies of iron carbonate. The iron industry of the Cleveland district in England is founded on a great deposit of this material,

locally known as "clay iron stone," and there are some deposits of great commercial importance on the continent of Europe.

LIMONITE

Limonite is a term commonly employed in commercial usage to describe all the common hydrated oxides of iron, of which there are three, turgite, goethite, and limonite, containing different quantities of water of crystallization ranging from 5.3 to about 14.5 per cent. This is the only distinction between them, and as limonite is much the more common in nature this name is applied to all three indiscriminately. They are also known generically under the name of brown ores, that being their characteristic color and the color of the "streak" which they yield under that geological test. The chemical formula for limonite is $2F_2O_3 + 3H_2O$ and its content of iron when pure is therefore 59.85 per cent.

Brown-ore deposits are probably more numerous than those of any other ore. There is hardly one State in the United States which has not deposits of sufficient size to be worked were the commercial conditions ordinarily favorable, but they do not ordinarily occur in as large masses as the magnetites and hematites.

The principal districts where such ores are now commercially mined in America are in western Massachusetts and Connecticut and eastern New York, eastern and central Pennsylvania, the western portion of Virginia, the central and western portions of Tennessee, the northwestern portion of Georgia, the northern portion of Alabama and northeastern Texas where limonite bodies of great commercial importance have recently been developed.

There are deposits of ore of this kind in various Western States, but on account of the unfavorable commercial conditions for the iron business on the Pacific slope no limonite ore bodies are at present in operation there on an important scale.

There are also brown-ore bodies of importance in the Lake Superior district, but those are not generally so highly hydrated as those in eastern and southern portions of the country, and for this reason, presumably, they are commonly not spoken of as limonites, but as "brown hematites."

In the Lake Superior district the ores range all the way from true hematite to true limonite, but the hematites predominate and for this reason give their name to all the ores of this class.

Limonite occurs as the immediate result of the oxidation of iron carbonate or other ferrous compound deposited by circulating water which carries the required oxygen. It may frequently be seen in the actual process of deposition at the present day, the best known illustration being that of the "bog ores." Streams carrying much vegetable matter in a region of ferruginous rocks dissolve the iron from these rocks and carry it in solution as a carbonate; or in combination with vegetable acids, to a lake or marsh where it has time to absorb oxygen from the atmosphere. This oxidizes it to ferric oxide which absorbs from its surroundings the necessary water of combination to convert it into limonite. This settles to the bottom and cements itself together as a true ore deposit.

The purity of limonite varies greatly and within short distances, even in the same mine, its content of phosphorus fluctuating considerably, but not as rapidly as that of silica which may range all the way from 3 or 4 per cent to 25 or 30 per cent without greatly affecting the appearance or even the specific gravity of the ore in certain conditions.

This ore is ordinarily low in sulphur, probably because of its aqueous origin and for the reason that the process of oxidation which converted it from the ferrous to the ferric form simultaneously oxidized any sulphur which it may have contained and so facilitated its removal in solution. These iron ores are commonly not so low in phosphorus as many others, limonite below the Bessemer limit in phosphorus being comparatively rare. A typical analysis of southern limonite as far as so variable a material can be said to have one is iron 45-48 per cent, silica 10-22 per cent, alumina 2-4 per cent, manganese 0.3-1 per cent, phosphorus 0.2-0.5 per cent, sulphur trace, combined water 9-11 per cent.

The principal characteristic of limonite in the blast-furnace is its extreme reducibility. The water of hydration begins to be driven off at quite a low temperature and is completely removed at 800 or 900 deg. Fahr. It is commonly believed that the driving off of this water facilitates the access of the gas to the interior of the ore and while the ore shrinks more in volume than it does in weight from dehydration, thus indicating that no porosity is developed thereby, its action in the furnace lends color to this belief, since it is the most reducible material with which the blast furnace ever has to deal. It is highly valued on this account particularly for admixture with less reducible ores on which it seems to exercise a beneficial effect.

HEMATITE

The ores embraced under this designation constitute the source of more than 80 per cent of the iron produced in America. Their origin is less obvious than that of the limonite, but it seems certain that in very many instances they were deposited originally as limonites and subsequently dehydrated by conditions of temperature and pressure resulting from some of the more important geological actions of the earth's crust.

The largest known deposits of iron ore in America and probably the greatest number of large deposits are hematites, but this name is employed to denote material covering a wide range of characteristics. As has already been mentioned, the partly dehydrated limonites of the Lake Superior region, which range from yellow to dark brown in color, are classified as hematites. The geological "streak" of true hematite is blood-red and that is its most common color. But it varies from the light yellow of the partly dehydrated limonites of Lake Superior on one hand to the blue-black ores which, still carrying the same name, have been partly converted presumably by still further heat and pressure, into magnetites. It also varies in physical structure from the "soft" ore almost without hard particles and nearly as plastic as clay itself to a dense crystalline structure so hard that a steel drill will scarcely attack it, and from a lumpy mass in which fines are almost absent to great deposits of such fineness that 75 per cent or more will pass through a hundred-mesh sieve. As to its content of impurities it is equally as variable, ranging from bare traces of sulphur and phosphorus to a sufficient quantity of these elements to bar its use as a furnace material.

The principal districts in which these ores are commercially mined in America are, first, the Lake Superior region; second, the Birmingham, Ala., district, and third, a district in Colorado and Wyoming which serves the plant of the Colorado Fuel and Iron Company.

The Lake Superior region is divided into five main ranges, as follows: The Marquette, the Menominee, the Gogebic, the Vermillion, the Mesaba and the Cuyuna, this being their order from east to west and approximately also the order of their chronological development.

These five ranges constitute probably the largest body of rich iron ore in the world, shipments being made from them at the rate of nearly 50,000,000 tons per

year with sufficient ore in sight to maintain this rate for many years to come.

The predominating characteristics of the ores from the different ranges vary considerably. All the Marquette and Menominee ores are either lumpy or soft, seldom or never fine like sand. The ores of the Gogebic are almost wholly "soft" or clay-like. The ores of the Vermillion are almost entirely extremely hard, there being virtually no soft and no fine ore. The ores of the Mesaba are almost without exception fine, seldom or never lumpy to any great extent and while sometimes clayey never so much as those of the Gogebic. The finest ores commercially used anywhere come from this range. The ores of the Cuyuna embrace all three varieties to some extent, but its discovery is so recent and its development so incomplete that it is not possible to say positively what the predominating characteristic of its ores will be.

The characteristics of these ores for use in the furnace depends in great measure on their physical structure. The hard, lumpy ores are less reducible than the fine and sandy or the soft ores, but are highly valued because the looseness with which they lie in the furnace permits the passage of the furnace gas through them much more easy than do the fine or the soft ores. The soft ores are characterized by high reducibility, and on account of their plastic nature are not much subject to being blown out of the top of the furnace by the gas current. On account of presenting less surface to the action of the gas than the extremely fine ores the initial changes in their condition occur more gradually and the furnace works better in consequence. Because of these characteristics, these ores are among the most highly valued of all varieties.

The fine ores present neither the free passage for the gas offered by the hard lump ores nor resistance to being blown out of the furnace like the soft ores, while the vast quantity of surface which they expose to the action of the furnace gas causes the initial reactions to take place in them with great velocity, thus further increasing their fineness and so rendering them still more likely to be blown from the furnace. Moreover, they tend to cause excessive solution loss. For these reasons it was almost impossible for furnaces to work on large percentages of these ores in the early days of their use, and even with the increase in knowledge of how to handle them they are still much less desirable than coarser or more plastic ores.

FERRIC FERROUS OXIDE OR MAGNETITE

The chemical formula of this oxide is Fe_3O_4 and its theoretical percentage of iron is therefore 72.4, higher than that of any other oxide of iron occurring in nature. Ores of this nature appear to have originated in three separate and distinct ways.

First, by a continuation of those conditions of heat and pressure which dehydrated limonite and converted it into hematite; these if carried far enough seem to have converted hematite in its turn into magnetite.

Second, this ore appears to have originated in many cases as a segregation from a mass of molten igneous rock; an igneous origin is attributed to some of the largest known bodies of magnetite.

Third, it is chemically possible to deposit magnetite from an aqueous solution of certain iron salts and it is possible that this may have been the origin of some ore deposits of this kind. This ore when approximately pure is distinguished by its intense black color and high specific gravity, also by its strong attraction for the magnetic needle. This is so great that the compass cannot be used for ordinary surveying in districts where there are considerable deposits of this ore. On the other hand, the deviation of the needle from its proper bearing, determined by the solar compass, indicates the presence of bodies of magnetite under the ground, though these are not necessarily of commercial importance on the strength of such indications. A special compass is used for this purpose in prospecting work to some extent.

Its magnetic condition gives this ore an important advantage over other ores since this makes it relatively easy to concentrate by magnetic separation from its gangue so that deposits of magnetite can be worked and rendered commercially available when lower in iron than can be permitted with non-magnetic ores. In addition to the relatively harmless gangue, elements are frequently removed in the concentration which would exercise a deleterious influence on the quality of the iron if it remained in the ore. This is particularly true of magnetites containing phosphorus. Lean ores high in phosphorus in their crude condition can in some cases be concentrated to Bessemer ores of exceptional purity. The process of magnetic concentration has been more highly developed in the Lake Champlain district in New York than anywhere else in the United States.

In its action in the furnace this ore differs greatly from limonite and hematite. It is generally much more dense than either of these and resists the reducing influence of the furnace gases, even at temperatures at which the other ores are almost completely reduced. For this reason a large portion of its oxygen can only be removed from this ore with solid incandescent carbon in the lower regions of the furnace. These conditions require that more time be given for the reduction of this ore than is necessary with the other varieties and in consequence the output of a furnace on a burden of this ore is smaller and its fuel consumption higher than those of a furnace using a hematite of similar composition and physical characteristics.

In addition to these natural ores of iron there are various iron-bearing materials which owing to their mechanical condition, or their mechanical composition, are not suitable for charging into the furnace in the condition in which they occur. These may be natural ores of abnormal composition or condition, or they may be the by-products of another industry.

Ores in many districts occur in conjunction with foreign materials which can be removed from them by simple means, this often rendering suitable for furnace use a material which it would be impossible to consider using in its native condition. Perhaps the most notable instance of this is the brown ores or limonites which, in a great if not preponderating proportion of mines, occur admixed with heavy clay and sand to an extent that renders the native material entirely unfit for the furnace, but by a simple process of washing with water, by means of vigorous agitation, the foreign material may be removed and a very desirable ore produced. Of all the limonite ores in the country it is probable that 90 per cent are so washed before they are used. In other cases these ores, and sometimes others, are admixed with pieces of barren rock, but so intimately that while in the larger sizes separation can be effected by hand-picking, in the smaller sizes it is necessary to use jigging, and various jigs have been developed which are extremely successful for this purpose. Probably the largest washing and jigging apparatus in the world is that at Coleraine on the Western Mesaba field where some 25,000 tons of material a day are handled, which are entirely unfit for blast furnace use as received, but from which some 15,000 tons of excellent ore are recovered.

Magnetic ores are often, if not generally, mixed with barren rock, and this being non-magnetic the ore can

quite easily be removed from it by magnetic separation. In order to make this feasible the material must be crushed to a degree of fineness which depends upon the intimacy of mixture between the rock and ore. The ores of Lake Champlain are particularly well adapted to this treatment, the individual mineral particles are quite large in the case of both the rock and the gangue, and being distinctly crystalline the minerals tend to separate at the crystal faces. This favorable condition combined with the enterprise of the owners has resulted in the development of magnetic separation at these mines on a large and very successful scale. In other mines such as that at Cornwall, Pa., the intimacy of the mixture is much greater and much finer crushing is required, while at the Moose Mountain mine in Canada the crystals are so small and so intimately mixed that the ore has to be ground almost as fine as flour before a satisfactory separation can be secured. This fine grinding brings the ore into the condition of other fine iron-bearing materials of which there are two principal classes, flue dust produced by the mechanical carrying over of the fine particles of the charge by the gas current, and pyrites cinder, commonly known as "blue billy," the residuum which is obtained from finely ground pyrites used for the manufacture of sulphuric acid. This material like the fine concentrates of the Cornwall mine contains from 1 to 2 per cent of sulphur; this with their fineness makes them an undesirable ore burden from the operating point of view because they are liable to a very heavy loss of the ore itself by blowing over; because they cause high solution loss, and therefore relatively high fuel consumption as already described, and because they have a tendency to travel ahead in the furnace, build up on the bosh walls, and then slide off in masses of sufficient size to put the furnace almost out of business, while the sulphur necessitates a limey slag and therefore still further raises the fuel consumption. For all these reasons then these ores must receive another treatment. Fine ones may be agglomerated or stuck together by processes not involving the use of heat, but for sulphurous ores some sort of roasting is desirable, if not absolutely necessary to get rid of the sulphur, and this operation can be carried on at a sufficiently high temperature to frit the ore, and stick the particles together in a plastic condition.

For the purpose of binding together fine ore without roasting various processes have been proposed and used. Ore has been mixed with cement, the setting of which stuck it together in lumps which could be charged back into the furnace. Clay has been used for the same purpose, but most of these cold processes depend upon the production of briquettes by pressure in combination with the use of a binder in some description.

In the scoria process ground hydrated furnace slag is used, and after the briquettes are formed under heavy pressure they are baked with high-pressure steam for several hours in a steel retort so that a further hydration takes place and the slag sets, acting as a binder.

The Schumacher Process makes use of the fact discovered by Dr. Schumacher in Germany that certain substances have a catalytic action on flue dust which causes it to set and harden somewhat like cement. Magnesium chloride and ferric sulphate are two of the substances successfully used for catalizers. The quantity used, and its cost, are not sufficient to cause a heavy charge against the product, while the quantity of sulphur introduced with the ferric sulphate is not sufficient in amount to effect the use of briquettes in the furnace in ordinary proportion. More recently it has been found that the fine dust separated from furnace gases by the Halberger-Beth system also had this catalytic power, and briquettes are being made with this material to contribute the cementing property, but not, as far as known to me, in this country.

All these briquettes are liable to disintegration if exposed to the weather, and if they are to be stored must be put under cover, otherwise they will decrepitate to a detrimental extent in a comparatively short time. A further fact to be considered in connection with them is this: they consist of the original particles of dust bonded together perhaps quite firmly, but still separate particles, with bonds capable of dissolution. The decomposing tendency of furnace gas on iron-bearing materials has been many times set forth. How far then will these briquettes progress down in the furnace before they are decomposed by the action of the furnace gas itself, and so returned to that objectionable condition of fineness which is one of the most important reasons for agglomerating them in the first place?

If this action takes place well above the top of the bosh we may have the high solution loss which it should be the principal function of agglomerating to prevent. Some effort has been expended by the advocates of these systems to prove the reducibility of their product, but if it be true, as I have shown in an earlier chapter, that a furnace may suffer as severely by too great reducibility of the ore as by too great irreducibility, the results of their efforts are not convincing. They may in fact be proving the very condition which would be worst.

Turning now to the processes of agglomerating by heat we have four which in the order of their development are the rotary kill, like a cement kill, usually fired with powdered coal, the up-blast converter pot of the Huntington-Heberlein type and the down-draft pot or pallet, and the tunnel furnace of the Gröndal type in which briquettes formed under pressure are burnt to strong and durable condition.

The fuel required for the first is about 15 or 20 per cent of the weight of the material agglomerated, when the latter is carbon-free material such as fine ore or bluebilly, but a less percentage in the case of flue dust. The up draft converter or pot is an apparatus not unlike a Bessemer converter with a grate in the bottom through which a strong current of air is forced by a positive pressure blower. A fire is built on the grate and this is covered over, when well started, with flue dust or ore (though this process has been used principally for flue dust), taking care so to place the material as to stop up the holes in the bed, and produce as nearly as possible a uniform blast over the whole surface. A little coal is thrown in from time to time with the charge, the air continuing to force its way from the bottom upward through the porous material formed. Only enough coal is charged to bring the material to a sticky condition so that the individual particles are partly fused together, and the blast blows holes through the mass while soft, making it spongy. When the pot is full it is tipped like a converter and the resulting "chunk" of sinter of many hundred pounds weight is broken up partly by its drop onto a grating and partly by hand sledging.

In the down draft apparatus a grate is provided at the bottom, but as the products are drawn down through the bed and reach the grate in their hottest condition it has been found necessary to cover the grate over with some harmless substance which protects it from the severity of the hot gas to some extent.

There are two down-draft processes, the Dwight-Lloyd and the Greenawalt. In the first an intimate mixture of the material to be sintered with as much fine coal or coke as may be necessary for the operation is spread upon the grate in a uniform and homogeneous layer. The top surface is ignited by a flame which plays upon it for a short time, and the down draft

through the mass pulls the plane of combustion gradually down to the bottom of the mixture, stopping on top of the inert material on the grate, this material being generally limestone spalls, which are not only harmless but are needed in the charge any way, and whose partial calcination is that much advantage to the furnace.

The difference between the Greenawalt and the Dwight-Lloyd processes is briefly that the former is a batch or charge process, one definite quantity being handled at each operation, whereas in the Dwight-Lloyd system the operation is continuous, the apparatus being in substance no more than a chain grade arranged for down draft. Both types of apparatus have their champions, and each claim advantages over the other, but they are very similar in principle and in product, so that eventually that one will probably win which can show the lowest operating cost. Both these types of apparatus produce a very desirable product. It is even more spongy than that of the up-blast pot while owing to the uniformity and better preparation of the charge before combustion begins a much larger percentage of properly sintered material is produced. The exposure of all the particles to the blast is excellent, and in consequence the desulphurization is good. Monthly records have been made in which blue billy ranging from 1 to 4 or 5 per cent in sulphur was reduced in the sinter to a very uniform figure of about 0.1 per cent.

The great advantage of the down draft over the up draft for sintering is that with the up draft the surface particles are in a constant state of agitation, than which nothing could be more unfavorable to sintering them together without producing an unduly pasty or liquid condition. In the down-draft apparatus, on the other hand, the surface layer, as well as all the other layers below it, are held to place by the passage of the blast through them. The agitation of the charge during sintering is, therefore, entirely eliminated and a larger percentage of the charge can be sintered as above stated.

This material has two great advantages for blast-furnace purposes. It is lumpy and irregular to the last degree; therefore, it is impossible for it to penetrate through the coke bed in the way that fine ore does. The particles have lost their separate identity and been merged into a homogeneous mass, and while the mass is black and, therefore, partly magnetic, it is claimed by those who have investigated that it does not consist in the main of magnetite with the irreducibility characteristic of that material.

Owing, on the other hand, to its physical and chemical composition this material does not suffer from the excessive reducibility of fine ores as above described. At the same time it is so porous and permeable to the gas that by the time it reaches the hearth of the furnace it is sufficiently deoxidized not to require extra fuel in the hearth for that purpose. Authentic figures are available which seem to indicate that an admixture of 15 to 25 per cent of this material in the furnace burden actually exercises a beneficial effect on the fuel consumption and the output.

As compared with the product of the rotary kiln this material has several advantages. If the material under treatment is to be desulphurized the greatest care is necessary with the rotary kiln not to heat the material above the softening point until the desulphurization is complete, as otherwise the small particles are stuck together into balls by the rolling of the kiln and seal up a sulphurous mass inside which no amount of roasting will desulphurize. The conditions are made more difficult by the fact that the melting temperature of the sulphides is very far below that of the oxides. Even if the material be thoroughly desulphurized in the kiln, as it undoubtedly can be, the agglomeration takes place by the rolling action of the kiln in bringing the pasty particles together, like the rolling of a snowball down a hillside, and this process necessarily tends to hammer out, or seal up, all pores which might accidentally form in the material, which is, therefore, dense and round, as compared with the porous, rough, irregular condition of the sinter produced by the passage of the blast through it. The consequence is that material produced in the kiln when used in mixture with softer and more reducible ores exercises a distinctly unfavorable influence on the working of the furnace necessitating slower driving and higher fuel consumption. This is a matter concerning which I have had definite and positive experience.

In addition to these materials there are others, by-products of other phases of the iron industry itself, notably an iron-silicate slag produced in the manufacture of puddled iron, heating furnace cinder, the scale from ingots or blooms charged into reheating furnaces for the purpose of bringing them to the rolling temperature, and mill scale, the black magnetic oxide of iron which forms on the red hot material being rolled, and cracks off at its passage through the rolling mill. The latter is almost a pure oxide of iron which is quite free from silica, but on account of being magnetic oxide is somewhat irreducible in spite of its rather finely subdivided condition.

The first two, as stated, are fused silicates of iron, the scale in the latter case fluxing itself with materials dissolved from the brick of the furnace. These materials are produced by true fusion, and complete chemical union of the iron with the silica. Ferrous silicate is in itself a very irreducible compound, probably the most irreducible with which we have to deal, while owing to its being produced in the completely molten condition, and in the absence of any passage of blast through it the material is exceedingly dense and impenetrable to the gas, thus increasing its irreducibility. These facts were well shown by some remarkable transparent slides like geologist's rock sections prepared by Mr. G. B. Klugh, and shown at the October meeting of the Iron and Steel Institute in Chicago in 1913. From the magnified image of the section thrown on the screen the differences in the materials were very apparent, and the reason for the superiority of sintered material over fused silicates became very evident.

THE USE OF THE DIFFERENT ORES IN THE FURNACE

The varying characteristics of these different ores, natural and artificial, affects their use in the blast furnace very materially. The variations are so numerous that it is impossible to deal at length with all of them, but we may touch upon some of the more important. Perhaps the most important is the difference between the magnetite and hematite, of which the former contains materially less oxygen in proportion to the iron and, therefore, contributes a small quantity of oxygen for the oxidation of the gases in the shaft, thus cutting down the heat development in the shaft materially. On the other hand, this ore retains its oxygen more strongly than does hematite and probably carries a larger proportion of its total oxygen into the hearth, so increasing the requirements of hearth heat for its final reduction and also increasing the solution loss of coke simultaneously. The result of these two actions undoubtedly causes magnetite ores to require more fuel and a longer time in the furnace for smelting, thereby increasing both the fuel cost and fixed charges for the iron so produced, and these causes have militated against the popularity of this ore in spite of the fact that it is fre-

quently quite rich, either naturally or by magnetic concentration.

Another factor of great importance is the size of the individual ore particles. If these are lumpy so that they cannot roll down through the coke charge solution loss is diminished, while the smaller surface presented to the gas in the zone in which decomposition of CO takes place probably reduces the extent of that catalytic action, and thereby diminishes the deposition of carbon dust with the evils which it causes by obstructing the interstices of the charge and so causing high pressure and consequent slipping in this zone.

If the ore be too lumpy, that is, if the individual lumps be too large, particularly with a dense ore, their exposure to the action of the gas is insufficient and either the ore is not properly reduced when it reaches the hearth, or else more time is required for that operation. If great variations in the size of the ore occur, some being charged quite fine and other as large lumps, then the lumps are reduced much more slowly than the fines and are likely to descend unreduced into the hearth causing raw slag and other bad operating conditions.

Plenty of cases are known in which the failure to break large lumps by the stock-house men charged with that duty has caused furnaces to work very badly, and ore should never be charged in that condition.

The evils of excessively fine ore, on the other hand, have already been pointed out. Its tendency to run ahead through the charge, its excessive catalytic action on the gas, and above all the excessive solution of coke which it causes render fine ores inherently less desirable than ores of the same analysis in a better physical condition.

It is also a matter of great importance that ores of different physical condition act very differently on the bell. The lumpy ores slide freely and with high velocity, the plastic ores, or fine ores containing alumina, slide very slowly and even build up on the bell. The consequence is they are delivered into the furnace at a much slower speed, and their position relative to the coke charge and the walls of the furnace is very different, so that a change from an ore of small lumps to one of coarse lumps in one direction, or of plastic fines in the other, all being of the same composition, would work considerable and probably serious changes in the operation of the furnace.

Flotation Symposium at Ottawa

A Report of the Papers and Discussions on Flotation at the Ottawa Meeting of the Canadian Mining Institute

The eighteenth annual meeting of the Canadian Mining Institute was held on March 1, 2 and 3 at the Chateau Laurier, Ottawa, Ontario. The proceedings were opened by the Hon. P. E. Blondin, Minister of Mines for the Dominion. The keynote of his address was that "this great world war has awakened Canadians to a realization of their country's unlimited mineral resources."

Mr. Arthur A. Cole, president-elect, in the chair, welcomed the members and guests and reiterated Mr. Blondin's remarks.

Five business sessions were held on the first two days, followed by the annual dinner. A very interesting trip on the last day was made, by courtesy of Dr. J. Bonar, deputy master, through the Royal Mint. Trips were also arranged to inspect the ore dressing and other laboratories of the Mines Department, the Museum of the Geological Survey and the National Gallery.

Mr. Arthur A. Cole, Cobalt, Ont., was elected president and Mr. Charles Fergie, Montreal, and Mr. D. B. Dowling, Toronto, vice-presidents, all by acclamation.

The two principal subjects of discussion at the meeting were the proposed new taxation of mining concerns, against which a resolution was unanimously adopted, and the flotation of ores. Of the flotation symposium we herewith give a full account. Four papers were presented in this symposium.

The Flotation Process

The first paper on the flotation process, by Mr. **T. A. Rickard,** which is published in full in the March issue of the *Monthly Bulletin* of the Canadian Mining Institute, pointed out that it is not yet four years since the starting of the first American mill using the frothing method of flotation, yet 55,000 tons of ore are being treated daily by this process in the United States today. This means 20,000,000 tons per annum. The larger part of these metallurgical operations began within the last two years. It is evident therefore that the process is gaining ground so rapidly as to command the intelligent attention of all those engaged in mining.

To Ben Stanley Revett the author gives credit for having recognized as early as twenty-seven years ago that the key to the flotation process is to be found not in the oil, the acid, or the apparatus, but in the bubbles.

The man who understands the physics of a soap bubble has mastered the chief mystery of flotation. To put it briefly, the boy, having dissolved soap in water, holds a little of it in the bowl of his clay pipe while he blows through the stem. The soapy water forms a film that is distended by the boy's warm breath into a lovely sphere, which is lighter than the surrounding air and therefore rises, while the sunshine undergoes refraction into the colors of the spectrum. When the boy blows through his pipe into pure water, he makes bubbles likewise, but they break instantly. It is the soap that lengthens their life. In the language of physics we say that high "surface tension" causes the pure-water bubbles to burst immediately, while the addition of soap introduces a contaminant that lowers the tension so as to enable the bubbles to last longer. The basic factor in the making of bubbles is surface tension.

The force of surface tension has been measured by ascertaining the weight that can be suspended from a film of water in air[1]. It has been stated as 3¼ grains per inch[2] or 81 dynes per centimeter.[3] The most recent determination is that of Theodore W. Richards and Leslie B. Coombs[4], who found it to be 72.62 dynes per centimeter at 20 deg. C. Many disturbing factors enter into the measurement of this force, so that diverse figures, ranging from 70.6 to 81 have been announced at different times.

Surface tension differs as between various liquids

[1] A Text Book of the Principles of Physics. By Alfred Danniell. 1911.
[2] "Soap Bubbles," by C. V. Boys.
[3] Clerk Maxwell in the *Encyclopedia Britannica*, under "Capillarity."
[4] The Surface Tension of Water, Alcohols, etc. *Jour. Amer. Chem. Soc.*, July, 1915.

and fluids in contact; for example, the tension separating mercury from water amounts to 418 dynes per centimeter, while that separating olive oil from air is only 36.9 dynes. A drop of pure water will spread over the surface of pure mercury as oil will spread over water. The surface tension of an oil-water surface is only 14, as compared with the 73 of an air-water surface at a temperature of 18 deg. C. While the film of oil on water may be only one molecule thick, or one twenty-five millionth of an inch, it will suffice to reduce the effective pull of the water surface from 73 to 43. This latter figure represents the effective surface tension of water modified by oil as used in flotation. It is the main factor in the formation and persistence of a bubble. Heat lowers the surface tension of water. Place powdered sulphur on the surface of the water on a horizontal plate of clean metal; apply heat locally; the sulphur is pulled away by the cold liquid as against the feebler tension of the warmer liquid.

The contractile force at the surface, whereby a portion of liquid gathers itself into spherical form, explains why the pure-water bubble bursts so readily. The high tension shatters it. It does not burst explosively, by expansion of the gas within the envelope, but by lateral displacement of the substance of the elastic film. It collapses because the surface tension draws it together. To prevent such immediate collapse it is necessary to lessen the tension; that is, diminish the contractile force in the elastic membrane constituting the film of the bubble. This can be done by introducing an impurity or contaminant, which lowers the surface tension; that is, diminishes the contractibility of the bubble-film. Water has the highest surface tension of any common liquid except mercury, so that the addition of another liquid usually lowers its surface tension.

Oil in emulsion and organic substances in solution can be used for this purpose. Soap will have the same effect, and that is why a soap bubble lasts longer than a pure-water bubble, the film of the former consisting of water having some soap in solution. When water has been modified by such a contaminant, the components of the film can so dispose themselves that the superficial forces will be the same everywhere; that is, tend to remain in equilibrium, including the force of gravity, which otherwise would pull the film apart.

When two bubbles come in contact they tend to coalesce because the two of them have an aggregate area greater than that required to include the same amount of air within a single bubble. In pure water the bubbles coalesce with a violence that is mutually destructive. Even when a survivor is left, the violence of coalescence of such bubbles in a pulp unhorses any mineral particles that may be riding the bubbles. When, however, the water is modified by oil, the contractile force of surface tension is diminished, the bubbles are less fragile, and they survive long enough to perform their metallurgic duty of buoying the metallic particles to the surface of the liquid pulp. In practice the "modification" of the water is effected by emulsification or minute sub-division (as in a mayonnaise) of an insoluble oil, such as cotton-seed and oleic; or it may be done by means of a soluble oil or derivative, such as cresol and amyl acetate.

The presence of a contaminant in water may also affect its viscosity or internal friction, whereby it offers resistance to a change of shape. This strengthens the film of a bubble generated in such water. Moreover, it has been asserted[6] that a concentration of the contaminant occurs in the surface of a liquid, causing the viscosity to be highly magnified as compared with the body of the liquid. It is also known that the films made of any definite liquid are of the same strength, irrespective of their thinness; so that the attenuation of the skin of a bubble does not decrease its strength. This again follows from one of the most remarkable properties of a bubble; the ability, within small limits, of adjusting its tension to the load.[7] Briefly, the tension at the surface of a contaminated liquid is able to adjust itself within fairly wide limits. Thus a film of liquid can remain in equilibrium when a film of pure liquid[8] would have to break.

In his book on flotation T. J. Hoover[9] states how the presence of a mere trace of saponine will kill the froth in the flotation cell. He does not explain why. It happens that saponine, which can be dissolved out of horse-chestnuts, is an aid to the blowing of big bubbles. But they are weak and tender. Why? Because saponine *increases* the tension.[10] . . .

In discussing the flotation process, the author points out that we are dealing with a pulp consisting of ore and water, modified by oil, the ore having been crushed sufficiently to separate the metallic sulphides from the associated gangue in a pulp consisting of minute particles of each. In ordinary water-concentration the lower specific gravity of the gangue permits the millman to wash it away from the heavier metallic sulphides, but in the flotation process this action is reversed, the metallic particles being lifted above, and away from the gangue particles. Apparently, it is a metallurgic anomaly.

To this crushed ore we have added oil. The oil serves as a contaminant that lowers the surface tension; also it augments the viscosity of the liquid. These two effects unite in faciltating the formation of strong and persistent bubbles. The necessary air is introduced by agitation or by direct injection. Sea-weed contaminates sea-water and makes foam in the breakers, as oil makes froth in fresh water that is agitated.

Air has a marked adhesiveness for metallic surfaces: this attachment is supposed to be enhanced by the presence of oil or grease on the metallic surface. In other words, the metallic surface, such as that of a sulphide mineral, when in the presence of both oil and water, will exhibit a preference for the oil. Hence the sulphide is not wetted. This characteristic is less marked on the part of the heavy silicates, such as rhodonite or garnet; and still less evident in the case of the lighter silicious minerals such as quartz and orthoclase.[11] The addition of acid lessens the oil attachment to the gangue particles without decreasing the selectiveness of the oil and the air for the sulphide particles. Thus we can understand why the bubbles attach themselves to the metallic particles and buoy them to the top, while ignoring the gangue particles, which sink to the bottom of the vessel in which the pulp is undergoing stirring or agitation. This preference of air for metals and metallic surfaces must be emphasized. It is the decisive factor in the process of flotation. . . .

When using the, at present, minimum quantity—say, one-third of a pound of oil per ton of ore—it would appear that the oil forms a coating of microscopic thinness upon the metallic particles. The minimum thickness is the thickness of a molecule.[12]

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[5]A Text-book of Physics. Poynting and J. J. Thomson, 1913.
[6]Samuel S. Sadtler in Minerals Separation *v.* Miami case, 1915.

[7]"Thermodynamics," by Willard Gibbs. Page 313. "In a thick film, the increase of tension with the extension, which is necessary for its stability with respect to extension, is connected with an excess of soap (or some one of its components) at the surface as compared with the interior of the film."
[8]In a chemically pure liquid it is impossible to form froth or multiple bubbling. Some differentiation of the components of a liquid is required to make a film.
[9]"Concentrating Ores by Flotation." Page 99, Second Edition.
[10]"Soap Bubbles," by C. V. Boys. Page 115.
[11]Kenneth A. Mickle. Proceedings of the Royal Society of Victoria. Vol. XXIV, Part 2, 1911.
[12]"Oil Films on Water and on Mercury." By Henri Deveaux. *Min. & Sci. Press*, July 31, 1915, page 156.

Metallic surfaces have a selective adhesion for air and for oil, as we have seen. Therefore the molecular forces of the oil and of the metallic surface may be supposed to unite in attracting the bubbles. What the nature of those forces may be is yet a matter of conjecture, although the idea that they are electrostatic is suggested by the fact, among others, that the metallic sulphides most amenable to flotation are good conductors of electricity.[13]

The foregoing statement of physical principles applies more particularly to the frothing method. In true bulk-oil flotation, which, as a matter of fact, was rarely performed, the phenomenon of surface tension does not play a prominent part. It is mainly a question of raising a mineral heavier than water by aid of a liquid lighter than, and not soluble in, water. The emulsification of the oil was carefully avoided by Elmore. In the later phases of flotation, in which the proportion of oil becomes steadily less, it is aimed to emulsify the oil and air. The oil produces a "micro-emulsion of air," as Leverrier expressed it. Thus the air is thoroughly distributed in the pulp and the oil is brought into intimate mixture with the water, which is thereby modified and prepared for the making of persistent bubbles.

The author then gives a concise statement, with illustrations, of the different flotation processes which are all more or less well known (Bradford, Macquisten, Wood, Totter, Delprat, De Bavay, Elmore, Cattermole, Minerals Separation, etc.). From this summary the author concludes it is clear that three processes are covered by the general term "flotation," and that to clarify the discussion of the subject it will be well to distinguish between

1. Film-suspension, as in the Wood and Macquisten methods.

2. Oil-flotation, as in the Robson and Elmore bulk-oil methods.

3. Bubble-levitation, as in the Elmore vacuum, Delprat, Froment and Sulman-Picard methods.

The third class can be further sub-divided according as carbon dioxide or air is the principal gas utilized for making bubbles. Finally, the air-bubble methods can be classified according to the way in which the air is introduced:

(1) From the bottom of the vessel, as in the Callow and Owen cells.

(2) By being entrained or dragged into the pulp by the beating of paddles or some other form of impeller, as in the Gabbett and Hoover mixers.

(3) By escape from solution in water, as in the Elmore vacuum machine and the Norris apparatus.

It remains to emphasize the fact that from the high ratio of 3 tons of oil per ton of ore the proportion of oil used in flotation has decreased, by reason of the recognition of the part played by air, to one-third of a pound per ton of ore; that is 1/18,000 of the quantity used by Robson. Concurrently the acid used has decreased to a minus quantity, namely, alkalinity.

The author then gives a concise summary and analysis of the patents on the flotation process and finally concludes as follows:

For the most part, until quite recently, the information available on the flotation process had come from patentees, their friends, and their enemies; a good many of the facts available have been elicited in the course of litigation, which has now been in progress for ten years; therefore a vast amount of nonscience has been mixed with the little science that has survived amid thoroughly uncongenial surroundings. Anybody familiar with the bitter business feuds and personal vendettas generated during the course of the quarrels over patent rights needs not to be told that keen prejudice, amounting in some cases to malice, has been injected into the ragged literature of flotation. The warping of scientific vision is astounding to the detached observer. Much that has got into print and more that has escaped a permanent record has been written with a jaundiced eye on the law courts. On top of this the metallurgy of the subject has been placed under an embargo of secrecy by the owners of the chief patents, and this has been effective to the extent of preventing the technical men in the employ of the process-mongers from contributing to current knowledge. Only recently has there been any considerable contribution from independent sources of information.

Another important element in retarding the technology of the process is the ignoring of the fact that it depends far more on physical than on chemical considerations. *To the physicist, not the chemist, we must look for guidance.* The metallurgist hitherto has depended upon chemistry to guide him; he must now go back to school and acquire something more than a smattering of physics, if he expects to understand the problems of the new process. To most of us chemistry comes more easily because it has a sign language, that of the formula, to convey ideas, while physics depends upon the use of terms, half of which beg the question. Hence the student must begin by rejecting the use of terms that he does not understand, and when he has learned to understand them he must take pains to define them whenever he undertakes to convey his ideas to others. By such sincerity of thought it will be possible to make real progress, and to apply science to industry with results far transcending any hitherto achieved in this field of human activity.

Discussion

Mr. G. D. Van Arsdale, New York, opened the discussion with the following remarks:

"Mr. Rickard's paper is extremely interesting and comprehensive, covering as it does the history, practical development, theory, patents and some of the litigation of flotation.

"The work which I have been doing has until recently been confined entirely to an attempt at an investigation of the theory of the subject, so that I can only comment on that portion of the paper relating to this.

"Any part of this subject is very complicated and difficult from a research standpoint, and it seems to me, therefore, that its study may be facilitated by making, when possible, some simplifying assumptions.

"The most prominent feature of our modern methods is the foam or froth. Let us consider what a foam or froth really is. A scientific definition would be a matter of some difficulty, but for practical purposes we can consider that a foam or froth is really only a collection of bubbles of greater or less size or number.

"We can, accordingly, simplify matters greatly by considering a single bubble. Now a single bubble may be very roughly defined as a surface of liquid in contact with or in some cases entirely surrounding a quantity of gas. With this definition we can make a still further simplification which is that what we ordinarily call a liquid surface answers to a part of this definition; that is to say, it is a liquid surface in contact with a gas, and we would accordingly expect a study of particles and oils on an ordinary surface to throw considerable light on the remaining much more complicated cases of practical flotation.

[13] "The Electrical Theory of Flotation." By Thomas M. Bains, Jr., *Min & Sci. Press*, Nov. 27 and Dec. 11, 1915.

"If, then, we ask why does a particle, heavier than water, float on a water surface we can attempt to answer this as follows:

"If the main cause is surface tension, there should be a definite relation capable of experimental verification between the maximum size of a particle that can float and the surface tension of the surface. It has been stated that the maximum weight that can be supported on a surface is equal to the surface tension, that is, 1 sq. cm. will support 81 mm. It can easily be shown, however, that 1 sq. cm. will support several times this weight, so that evidently the relation is not as stated.

"From certain surface tension formulae, however, we can calculate the maximum-sized particle of certain shapes—for example, cylinders, that will float, and experimentally, for example, with clean copper wire of various sizes, the actual size that will float is very close to this theoretical maximum.

"This proves absolutely, therefore, that we are correct in assuming surface tension as one of our main causes. Other conditions, all of which can be proved experimentally by simple experiments are:

1. Size and specific gravity of particle.
2. Shape of particle.
3. Inherent quality of surface to resist wetting.
4. Films.

"It is easy to show experimentally, as we also know from practice that some films prevent and others promote flotation, also that these films may be either a solid, a liquid or a gas or an electric film; that is to say, an electrostatic charge.

"Now summing up the above, we can state that a substance specifically heavier than water may be made to float, provided the size of particle be small enough, or proper shape, with respect to size and specific gravity, and provided it has a surface film sufficient to prevent wetting, which film may be either a solid, a liquid, a gas or an electrostatic charge or a combination of these.

You at once see that this statement is very close to a similar statement as to the conditions producing colloids, and the study of colloids as applied to flotation will, therefore, doubtless clear up the subject considerably.

"The main conclusion we have reached in the application of the above to the more complicated cases of actual flotation practice is that surface tensions and the resultant of these which determine wetness or non-wetness of particles is the 'how' of flotation or, in other words, the immediate cause or mechanism of the results, and that the study of the colloids and electrostatics will furnish the 'why' or the ultimate cause. Electrostatics will very probably act as one of the explanations of wetness or non-wetness, and also possibly as one of the explanations for the attachment of films.

"The study of flotation oils at first glance also seems hopeless in view of the number of these and the number of possible combinations, but we can also simplify this very much if we consider them from the standpoint of their functions.

"Their main functions are evidently two:

"1. To furnish a non-wet film on the particle.

"2. To furnish a froth by reducing the surface tension.

"This at once gives us a classification of oils into two kinds with respect to these functions:

"1. Oilers.

"2. Foamers.

"By taking into account also the interaction of physical qualities of one or the other in a mixture, we can have a somewhat rational basis for this study.

"What we apparently have not so far obtained and need very much is a definite understanding and statement of the specific physical qualities of the oils themselves which they need to enable them to fulfil these functions and, as a result of this, a rational and scientific method of testing for their selection and use."

During the following discussion Mr. **H. W. Du Bois,** Philadelphia, pointed out that the phenomena of flotation are apparently so simple that the "reason for" has been lost sight of. The art has been developed much more rapidly than the theory.

Dr. **A. Stansfield,** McGill University, brought forth a burst of applause by saying that in considering a study of soap bubbles and their relation to flotation he could not rid himself of the idea that "the reason soap bubbles stick together is because of the stickiness of them."

Flotation of Bornite

Mr. **H. W. Du Bois,** Philadelphia, Pa., presented the second paper of the symposium, dealing with the flotation of bornite.

In Hoover's book it is stated that it is impossible to treat by flotation ores containing a chalcocite or bornite. Mr. Du Bois pointed out that this was an error, for chalcocite is easily flotable. Bornite, however, is quite another "nut" to crack. Bornite is always accompanied by a surface film ordinarily considered now to be "limonite," and this prevents the oil from coming into contact with the mineral particle.

In an attempt to overcome the film effect on their oxidized ores, the Braden Copper Company started introducing the oil during the crushing period, so that a more intimate contact was obtained while the mineral surfaces were fresh. They found that it was possible to greatly increase the recovery in this way on all ores containing oxides or minerals with drusy surfaces, but recovery is by no means good even yet.

When the feed is low grade the loss due to the content of bornite is not important, but when high, as it is in the Alaskan field (sometimes 20 per cent), it is most important.

The first attempt to overcome the effect of this "limonite film" on the Alaskan bornite ores was a repetition of Braden's more or less successful work—that is, by means of fine crushing, but this was a failure. It is, of course, possible to remove this "film" by using sulphuric acid, but in an isolated field like Alaska the high cost of acid makes its use prohibitive.

The difficulty of the problem led to a closer study of the "reason for" flotation, and the electrostatic theory seems to be the best explanation of the problem.

Assuming this theory to be correct, then we can say that in flotation we have a system in which the mineral particles are positively charged and the gangue negatively. The oil particles are negatively charged, and so adhere to or "wet" the mineral particles and repel or do not "wet" the gangue particles. If then we consider that for some reason bornite is negatively charged, we have at once an adequate explanation of the fact that bornite has been unflotable.

Some work has been done along this line, and it has been found that by treating bornite to the fuming action of nitric acid, it is then readily flotable. This is simply a change of polarity due to high temperature, the negatively charged bornite becomes positively charged and is immediately "wetted" by the oil and floats. It is hoped that a further study along lines suggested by the electrostatic theory will yield very important commercial results.

Mr. Du Bois stated that a number of companies control the feed to the flotation unit and keep it low in

order to get high extraction. This possibly is correct, but their experience with high-grade ores has been that this is entirely unnecessary.

Recent Improvements in Conditions at the Washoe Reduction Works, Anaconda, Mont.

The next paper in the flotation symposium program dealt with the flotation equipment at Anaconda, Mon., the author being Mr. E. P. Mathewson, Anaconda.

On Jan. 25, 1916, the last section of the remodeled concentrator of the Washoe Reduction Works, Anaconda, Mont., was placed in commission.

Water concentration has been retained for everything above 2 mm. in diameter, this being the maximum size of material sent to Hardinge mills for grinding, the product of Hardinge mills being treated by the Mineral Separation Company's flotation process.

The concentrator consists of eight sections, each having a capacity of 2000 tons of feed daily, or allowing for repairs, etc., a total average capacity for the entire mill of 15,000 tons.

In the crushing department, there is no essential change, and the Harz jigs and upper tier of Evans jigs are as before. The two lower tiers of Evans jigs have been taken out and one set of 18 Wilfley tables, with Butchart riffles, substituted. These tables are roughers, and here ends the water concentration.

Next come the Hardinge mills, which replace the Huntington, but grind much finer. The discharge of the Hardinge mills goes to three Mineral Separation Company's machines in each section, while the slime from the upper part of the mill removed on the overflow of Anaconda classifiers is treated in a fourth Mineral Separation Company's machine after being thickened to 16 per cent solids in 28-ft. Dorr thickener. The remainder of the slime with 1000 tons daily from an old deposit is treated in a special slimes flotation building, fitted up with twenty Mineral Separation Company's machines. The concentrates from all the Mineral Separation Company's machines is transferred by launders and elevators to 50 x 12-ft. Dorr thickeners and hence to Oliver filters. The overflow of the Dorr is sent to large settling ponds to recover any values in froth that may not have settled out in the same.

The average grade of the feed to the mill is 3 per cent Cu. Twenty-five per cent of the feed is removed in the upper part of the mill in the form of concentrates by water concentration; 11.50 per cent is recovered as concentrates from the flotation machines. The average tailings (slime and sand) run 0.15 per cent Cu. This, after allowing for loss in overflow and leakage, gives a net recovery in form of concentrates of 96 per cent of the Cu. in the original ore.

The tailings from the flotation machines have been found to be quite suitable for the manufacture of building brick and a plant with a capacity of 17,000 bricks daily is now operating on this material.

The equipment for each of seven sections of the concentrator is as follows:

1—12 x 24-in. Blake crusher.
2—8 x 20-in. Blake crushers.
6—Coarse concentrate Harz jigs.
6—⅜-in. concentrate Evans jigs.
12—Fine concentrate Evans jigs.
4—Sets of 55 x 24-in. rolls.
18—Wilfley tables—Butchart riffles.
8—8-ft. Anaconda classifiers.
6—7½ x 72-in. Hardinge mills with individual 225-hp. motors and using steel lining and steel balls.
6—Dorr simplex classifiers inclosed circuit with Hardinge mills.
4—Mineral Separation Company's flotation machines having 15 agitators and 14 spitzkastens each, and individual 150-hp. motors.

The necessary elevators, trommels and dewatering tanks.

Section No. 1 has four fine concentrate Hancock jigs, instead of Evans jigs, and uses 8-ft. x 12-ft. tube mills instead of Hardinge mills, the balance practically as stated above.

The product of water concentration is drained in suitable tanks and then transferred in cars to the smelters.

The concentrates from the Mineral Separation Company's machines are thickened in Dorr thickeners—50 ft. in diameter and 12 ft. in depth—and the thickened material is filtered in Oliver filters, from which it is conveyed on belts to the roasting plant. The tailings are sluiced to the dump by waste water from the mill.

The horsepower required per ton of ore is 0.96, divided as follows:

	Hp.
Feeding and coarse crushing	125
Roll crushing	220
Jigging	60
Screening	37
Conveying and elevating	237
Table concentration	25
Fine grinding	655
Flotation of sands and slimes in mill	426
Dewatering mill slime pulp	3
Flotation of slime in slime division	109
Dewatering flotation concentrate	25
Sampling and assaying	1
Total hp.,	1923
Tonnage daily,	2000
Per ton,	0.96

DESCRIPTION OF MINERAL SEPARATION COMPANY'S FLOTATION MACHINE, AS INSTALLED IN CONCENTRATOR AT WASHOE REDUCTION WORKS

The feed is introduced into the first agitator box at the motor end of the machine. From this box it passes to the second box through an opening in the partition. From this second agitating compartment the pulp passes into the first spitzkasten, where the first concentrate froth is removed by means of a paddle, and the remaining pulp passes through a pipe—the inlet to which is controlled by valve to the third agitating box from this on down through the machine until the pulp is introduced into the fourteenth spitzkasten. The discharge from the fourteenth, or last spitzkasten, leaves the machine as tailing. The first four to seven spitzkastens make a finished concentrate, and the remaining spitzkastens make a middling which is returned to the system.

The drawing (not reproduced here) shows a double machine, each machine, however, being run as a separate unit. The line shaft is driven by a 150-hp. motor at a speed of 385 r.p.m The machine under load requires about 100 hp. The vertical shaft carrying the impellers revolves at a speed of 223 r.p.m.

The impellers are the usual Mineral Separation Company's type, having four blades placed at 45 deg. to the vertical. The impellers are 2 ft. in diameter. Each pair of impellers is arranged so that one impeller revolves in one direction and the other revolves in the opposite direction—this tends to balance the side thrust of the line shaft. The bevel gears which drive the impeller shafts are cut steel gears and run in grease. The impeller shaft is supported both vertically and horizontally by ball-bearings.

Some of these machines have now been in operation for very nearly a year, and thus far it has not been found necessary to change any of the gears.

It has been found of advantage in some cases to place a motor on the other end of the machine if it is necessary to heat the pulp above 100 deg. Fahr. There is

more or less steam arising from the pulp, especially at the feed end which condenses on the motors, and by placing the motor at discharge end this trouble is practically eliminated.

Mr. H. W. Du Bois, in discussing this paper, wanted to know "why Anaconda was reverting to heated solutions and the use of acid which more recent practice has been trying to eliminate." Their use suggested to him that possibly they were up against the "bornite problem," just as his company has been.

Concentration of Canadian Molybdenite Ores

The last paper of the flotation symposium related to the concentration of Canadian molybdenite ores, the author being Mr. **Harry E. Wood**, of Denver, Colo. The author has tested a large variety of molybdenite ores from the United States and Canada, and shipped fifteen tons of concentrates from his mill in Denver, Col., in 1915. He states that the few hundred tons now annually consumed have been derived chiefly from the hand-sorting of the crystals or scales and flakes, and from hand-screening work. Consumers have been accustomed to purchase hand-sorted ore generally negotiated on the basis of 90 per cent MoS_2. He describes concentration by flotation in the Wood machine (a description of which was given in our issue of March, 1912, p. 132). The mechanically recovered concentrate averages 70 to 75 per cent and brings in most cases as high a price per unit as the higher percentage concentrate. The shortage of tungsten has stimulated the use of molybdenum as a substitute, and at present the price of molybdenum is four times normal as compared with a ten times increase in the price of tungsten.

The author visited a number of molybdenite mines in British Columbia and Ontario and tested samples from Quebec and Newfoundland. The fine but distinct crystals that are uniformly distributed throughout the gangue can be treated by flotation better than an ore containing large and irregularly distributed crystals, and sometimes consumers specify a 20-mesh product so that grinding of large crystals is necessary. When the ore is crushed before treatment the treatment and equipment are simplified. Experiments have shown that the ore should be crushed, and not ground or pulverized. For crushing, either rolls or ball mills are recommended. The use of ball mills is preferred, as with the use of rolls there is a tendency to roll up the semi-malleable flakes or to shape them so that they do not present a suitable area for flotation. The removal of large scales by screens or trommels is recommended. but the scales should be recrushed and floated. The ore is fed to the flotation machine directly without any sizing, if it has been crushed to 20, 30 or 40 mesh.

It is sometimes necessary to retreat the flotation products to remove iron, mica, etc. A Wetherhill magnetic separator has been used for this purpose. For recleaning concentrates a Wilfley table is of great assistance. When the gangue is a hard quartz the treatment is easy, but when chalcopyrite is present it floats with the molybdenite. The concentrate is in this case dried and refloated, the copper sulphide sinking, due to slight oxidation. The presence of graphite is not detrimental, although it is apt to be taken for molybdenite. Mica only affects the grade of the concentrate. Canadian molybdenite ores occur in a wide variety of sulphides and other minerals, and offer a complex problem for separation, but the characteristics of molybdenite are such that it can be separated if properly investigated.

Flow sheets for treatment and the results of preliminary tests and commercial operations are included in the paper.

Flotation Concentration at Anaconda

Among the important papers that have been announced for the Arizona meeting of the American Institute of Mining Engineers next September is that of **Frederick Laist** and **Albert E. Wiggin,** respectively metallurgical manager and superintendent of concentration for the Anaconda Copper Mining Co. The authors relate in detail the experiments conducted at Anaconda in flotation concentration, give a description of the remodeled concentrator as adapted to flotation, and also describe the new slime-flotation plant. From advance proofs of the paper we abstract some essential data.

The machines tested were of the following types: Standard Minerals Separation, Callow pneumatic, Froment, Towne, Fields, Anaconda and Minerals Separation sub-aeration. A large variety of oils was tested. The pulps treated were round-table feed and tailing, and current mill tailing. Round-table feed is the total slime from the mill, containing about 35 per cent colloidal solids, with about 90 to 95 per cent of total solids finer than 200-mesh. It assays from 2.3 to 2.6 per cent copper. The mill tailing is the total discard from the mill exclusive of the slime. It is all finer than 2 mm. and about 90 to 95 per cent will remain on 0.25 mm. It assays about 0.6 per cent copper.

In preliminary tests many reagents were used, with the result that it was conclusively proved that the best combination was sludge acid, wood creosote, stove oil and sulphuric acid. Fortunately these happened to be the cheapest of all reagents tested. Stove oil has since been omitted, but sulphuric acid was found of decided advantage in the treatment of slime.

Tests with Standard Minerals Separation Machine

Treatment of Round-Table Feed and Tailing.—From a series of tests under varying conditions as to temperature, density, reagents, etc., the following conclusions were reached:

1. The economic capacity of the M. S. No. 1 machine when treating slime as produced from the mill at present (May 1, 1915) seems to be from 80 to 90 tons.

2. The best combination of reagents for the treatment of slime seems to be sulphuric acid, kerosene sludge acid, wood creosote and stove oil. There is some question as to the real value of the stove oil. Its principal function seems to be to make a more compact froth.

3. It would not be economical to retain the round tables as the recovery by treating the slime directly by flotation is just as high as by retaining the round tables and treating the round-table tailing by flotation. The grade of concentrate would probably be the same in either case, but any difference would be in favor of treating the round-table feed directly by flotation. The heating of the round-table tailing pulp, on account of its low density, would increase the cost of the flotation.

4. In treating the round-table feed directly by flotation, the resulting tailing should assay 0.30 per cent Cu, or less, with a concentrate carrying not over 40 per cent insoluble. Possibly the concentrate can be made much cleaner with no sacrifice in the recovery.

5. It is thought that the best circuit density for the slime pulp for flotation treatment is about 12 per cent solids.

6. It is thought that about 70 deg. Fahr. will be found to be the most economical temperature at which to keep the pulp.

7. Acid seems to be absolutely essential to the successful treatment by flotation of our slime.

8. The addition of air in the last spitzkasten is of no advantage.

9. Any considerable increase in speed of the agitators above a peripheral speed of about 1300 ft. per minute seems to be disadvantageous.

Treatment of Mill Tailing after Grinding through 60-Mesh.—Dewatered tailing was crushed in either a Hardinge or tube-mill operated in closed circuit with a Dorr classifier. At first no sulphuric acid was added and the pulp was not heated. It was found advantageous, however, to use acid in addition to the 50 or 60 per cent contained in the sludge acid kerosene. It seemed also to be of advantage to add the oil ahead of the grinding mill, using that as an agitator. Difficulties developed, however, due to corrosion by the acid and the small amount of copper sulphate formed. From the numerous tests conducted along this line the following conclusions resulted:

1. Although not definitely demonstrated, it is thought that the economical capacity of the M. S. No. 1 machine when treating sand tailing crushed through 60 mesh is about 175 to 200 tons per 24 hr.

2. The best combination of reagents seems to be sludge acid kerosene and sulphuric acid. However, a mixture of creosote, turpentine and pine oil, in a non-acid circuit gave good results also. The non-acid circuit, however, seems to require more delicate adjustment and more careful attendance than the acid circuit.

3. The grinding mill makes an ideal agitator, and it is of decided advantage to add the oil ahead of the grinders.

4. The treatment of the mill sand tailing ground through 60 mesh should result in a tailing assaying not over 0.10 per cent Cu and a concentrate carrying not over 30 per cent insoluble.

5. It is thought that the best density of pulp is from 25 to 30 per cent solids.

6. Heating of the pulp to about 70 deg. Fahr. seems to be of advantage, although there is a possibility that this heating may be dispensed with during the summer months without any injurious results.

7. Acid seems to be beneficial, but it is not of as much importance as in the treatment of the slime.

From tests on the treatment of a mixture of round-table feed and mill tailing after grinding through 60-mesh, it was decided that it is better to treat each separately.

Tests with the sub-aeration Minerals Separation machine were not satisfactory.

Tests with Callow Pneumatic Machine

The equipment consisted of five standard Callow cells, 2 ft. by 8 ft., a Pachuca tank for mixing, and blower and sand pumps. Power readings on the blower gave the following results:

Air Pressure, Pounds	Input to Motor, Hp.	Shafting, Hp.	Net to Blower,* Hp.
4	25.8	8.8	17.0
5	35.4	8.8	26.6
6	47.4	8.8	38.6

* Includes motor loss.

Treatment of Round-Table Feed and Tailing.—As a result of several tests using both air agitation and mechanical agitation, the following conclusions were reached:

1. On our slime, air agitation is not as satisfactory as mechanical.

2. The capacity of one standard Callow cell is about 15 to 20 tons of slime per day.

3. The Callow machine produces a clean concentrate but does not give as clean a tailing as the Minerals Separation machine.

4. The Callow machine is more sensitive and requires closer attention than the Minerals Separation machine.

5. The cost of repairs would probably be less on the Callow machine than on the Minerals Separation machine. This cost, however, is comparatively small for either machine.

6. The power required per ton treated in the Callow system is just about the same as that required in the Minerals Separation machine.

Treatment of Mill Tailing after Grinding through 60-Mesh.—In the preliminary tests it was found that the mechanical agitators were not needed, sufficient agitation being given in the grinding mill. Sludge acid kerosene was the only oil used, and was added ahead of the grinding machine. Sulphuric acid was added ahead of the flotation cells. The tailing for the period averaged 0.1 per cent copper and the concentrate carried an average of 42.2 per cent insoluble. In this preliminary period the pulp was heated ahead of the flotation cells.

In subsequent periods various modifications of treatment were tried, using acid and neutral solutions and different oil mixtures. The conclusions reached are as follows:

1. The capacity of the standard Callow cell when treating ground mill tailing is about 75 tons per day.

2. No other agitation is required if the reagents can be added ahead of the grinding mill.

3. The use of acid seems to be of considerable advantage.

4. On account of utilizing the grinding mill as an agitator the Callow machine requires less power than the Minerals Separation machine.

5. The Callow machine is more sensitive and requires more attention than the Minerals Separation machine.

The work of the Froment and Towne, and the Fields flotation machines, was found to be unsatisfactory; that on the Anaconda cell was of short duration, no definite results being obtained.

The final conclusions drawn from all tests were that the Minerals Separation machine was best adapted to the flotation work at Anaconda, and that the most efficient reagents would be sludge acid kerosene, wood creosote and sulphuric acid.

Remodeled Concentrator Adapted to Flotation

The Anaconda concentrator as remodeled for flotation consists of eight units, each of 2000 tons capacity per day. All are alike with the exception of section 1, in which Hancock jigs are used instead of Evans jigs, and tube-mills in place of Hardinge mills. A flow-sheet of the remodeled plants is given in Fig. 1 (p. 330).

The flotation division consists of four Minerals Separation machines, each having fifteen agitators 3 ft. square, and fourteen spitzkästen or floating compartments. The agitators for the Minerals Separation machines are of gun metal and are driven by bevel gears from a line shaft, the direction of rotation of the agitators alternating.

The machines are made of California red wood; the agitator boxes are further lined with hard maple extending about 18 in. from the bottom of the box.

Each machine has an individual drive, power being supplied to the line shaft by a 150-hp. motor running at 385 r.p.m. The speed of the agitators is 225 r.p.m., and as the impellers are 18 in. in diameter the peripheral speed is about 1060 ft. per minute.

Each machine makes three products, a concentrate, which goes to the dewatering division, a middling which is returned to the head of the machine, and a

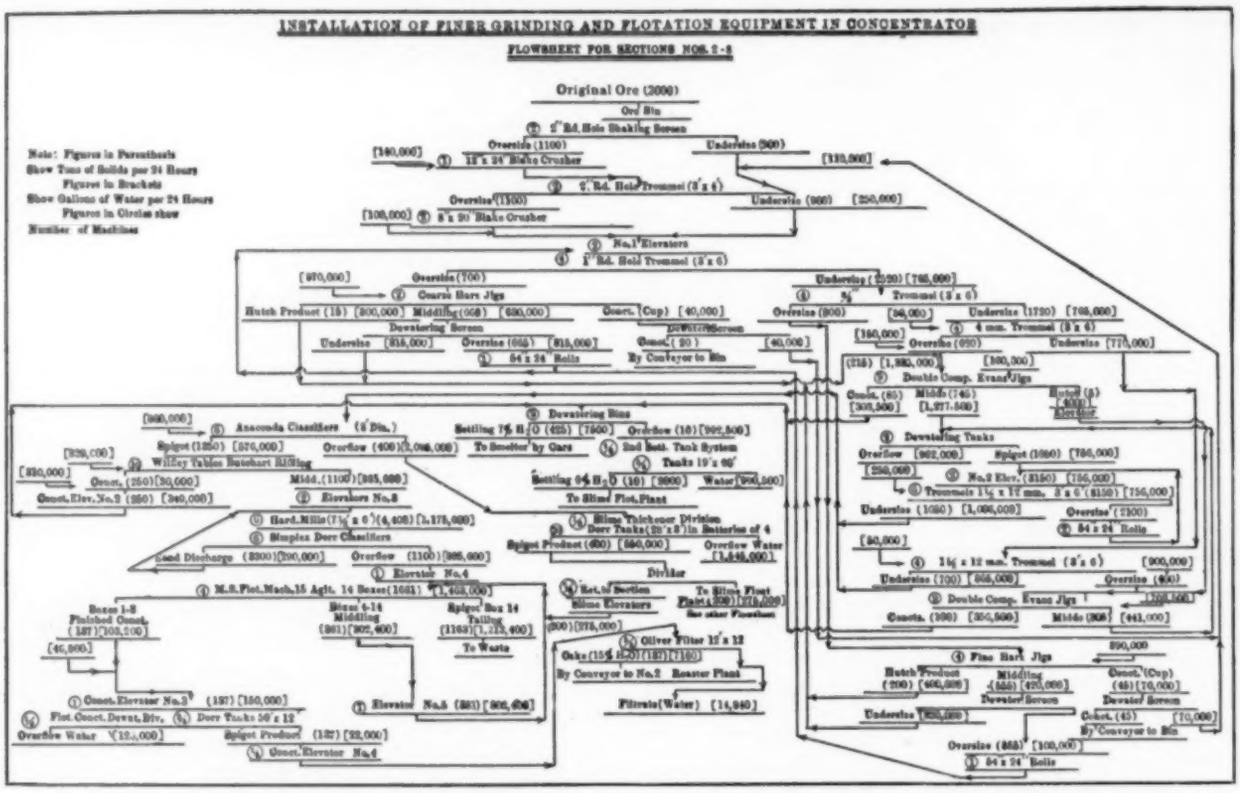


FIG. 1—INSTALLATION OF FINER GRINDING AND FLOTATION EQUIPMENT IN CONCENTRATOR

tailing which goes to waste. The concentrate is taken from the first three to five spitzkästens and the middling from the last nine to eleven. A portion of the pulp is overflowed from the last three spitzkästens together with the froth. About 6 to 8 lb. of (50° Bé. H_2SO_4) per ton of flotation feed is used together with 2 to 3 lb. of kerosene sludge acid and ½ to 1 lb. of crude wood creosote. A portion of the wood creosote is added ahead of the Hardinge mill (about 0.03 to 0.05 lb. per ton of feed) and the remainder is added in the sixth agitating compartment. The sulphuric acid and sludge acid are added at the head of the machine. The pulp is heated to from 60 deg. to 70 deg. Fahr., by passing live steam into it at the head of the machine. Three machines are used for treating sand and the fourth for treating current slime from the upper portion of the mill. Each machine has a capacity of about 400 tons per day on sand and 175 tons on slime.

The method of adding the oil and acid is rather unique. The mechanism consists of a revolving disk to which are attached, around the circumference, a number of cups. This disk is set vertically so that its lower edge dips into a pan of acid or oil. As the cups come around they are filled and later discharge their contents into a suitable launder leading to the flotation machine. The disk is driven by the friction of a wheel against another disk attached to the main drive. The wheel is run at constant speed and by varying the point of contact between wheel and disk any speed desired can be given to the main disk and thus the amount of oil or acid added can be regulated. In addition to the speed regulation, the amount of oil or acid fed may be varied by adding or removing cups or by changing the size of the cups.

At present (December, 1915) seven sections are operating on the new flowsheet, and the whole mill will be remodeled not later than Jan. 15, 1916. The sections are being remodeled one at a time. All the work is being done by the company's engineering force. Things have been so well organized and systematized that it requires less than 30 days to tear out the old section and install the new equipment, ready for operation.

The following table gives metallurgical data concerning the operation of the mill. Line 1 gives the monthly assay of second-class ore for October, which is the feed to the mill. Line 2 gives the monthly assay of the flotation tailing from the remodeled sections for October. The feed to the flotation machines during the month consisted of reground sand tailing and a portion of the thickened mill slime which was returned to the mill and treated in the fourth machine in each remodeled section. The tailing assay shown below, 0.13 per cent Cu, is for the total sand and slime tailing produced. The sand tailing alone averaged 0.10 per cent Cu and the slime tailing averaged about 0.25 per cent Cu.

	P.C. Cu	P.C. SiO_2	P.C. Al_2O_3	P.C. Fe	P.C. S	P.C. CaO	Oz. per Ton Ag	Oz. per Ton Au
Feed to concentrator	2.85	59.1	9.4	10.6	11.8	0.6	2.00	0.0070
Total concentrator tailing (flotation)	0.13	81.6	11.3	1.0	0.5	0.5	0.10	0.0005

No complete analyses of the flotation concentrate are available, as the slime flotation plant is not in operation yet and the round-table concentrate is being mixed with the flotation concentrate from the mill.

Following is an estimate of the power consumption per 2000-ton section, including its proportion of slime treatment.

	Power Consumption per Section, Horsepower
Feeding and coarse crushing	125
Roll crushing	220
Jigging	60
Screening	37
Conveying and elevating	237
Table concentration	25
Fine grinding	655
Flotation of sand and slime in mill	426
Dewatering mill slime pulp	3
Flotation of slime in slime division	109
Dewatering flotation concentrate	25
Sampling and assaying	1
Total	1,923
Horsepower per ton of ore	0.96

Description of Slime-Flotation Plant

Because of lack of space in the mill an auxiliary plant had to be installed to handle the extra slime. This plant consists of 20 Minerals Separation machines of the same type and size as those used in the concentrator, and five 50 by 12-ft. Dorr tanks for dewatering the concentrate. The plant is designed to treat about 2000 tons of current slime and 1000 tons of pond slime.

What this plant may be expected to do, so far as the treatment of current slime is concerned, may be judged from the results obtained in the experimental slime machine, which has been operating regularly for more than a year.

The following table gives the analysis of the current slime and the assay of the composite tailing sample for the month of June. These are typical of the results which may be expected in the large plant.

OPERATION OF EXPERIMENTAL SLIME-FLOTATION PLANT

Per Cent.	Feed (Current Slime)	Tailing	Concentrate
Cu	2.10	0.27	12.0
SiO_2	61.00	67.70	20.0
FeO	4.10	2.70	28.0
S	4.40	1.10	
Al_2O_3	19.00	18.30	
CaO	0.60	0.70	
Ag[1]	1.80	0.20	
Au[1]	0.005	0.001	

[1] Ounce per ton.

The treatment of the pond slime offers a few more difficulties than that of the current slime. This slime has been exposed to the weather for a number of years so that the copper is partially oxidized, consequently that portion probably cannot be floated. Some results from the flotation plant at Great Falls, covering a week's operation, are tabulated below. This character of material has been treated for some time at the Great Falls plant, and the results should be a good criterion of what may be expected here in the treatment of dump slime.

OPERATION OF SLIME-FLOTATION PLANT AT GREAT FALLS

	Per Cent
Recovery based on concentrate	78.90
Recovery based on tailing	80.90
Average total Cu in tailing	0.53
Average soluble Cu in tailing	0.13
Average sulphide Cu in tailing	0.40
Average total Cu in feed	2.52

A flow-sheet of the slime-flotation plant is given in Fig. 2.

Experiments in sulphidization at Great Falls, using sodium sulphide in solution, were not satisfactory. Practically all the dissolved copper was easily sulphidized, but not all the oxidized copper was dissolved during its passage through the machine. Difficulty was found in maintaining the froth, and a large part of the natural sulphides did not float. The cause of the breaking of the froth is not clear, but may be due to impurities in the sodium sulphide.

Dewatering of flotation concentrate is done in Dorr thickeners, 50 ft. by 12 ft. The pulp is delivered to a baffle box about 5 ft. square, in the center of the tank and extending down to within a few inches of the rake arms. Surrounding this is another baffle about 15 ft. square and extending about 18 in. below the surface of the water. A water spray is used to break up froth. When treating concentrate the capacity of these tanks is from 200,000 to 250,000 gal. of pulp per 24 hr. As there is a small amount of fine material that will not settle, the overflow is run to a slime pond for future treatment. Tests with glue to aid settling did not prove satisfactory. The density of the pulp delivered to the tanks is from 18 to 20

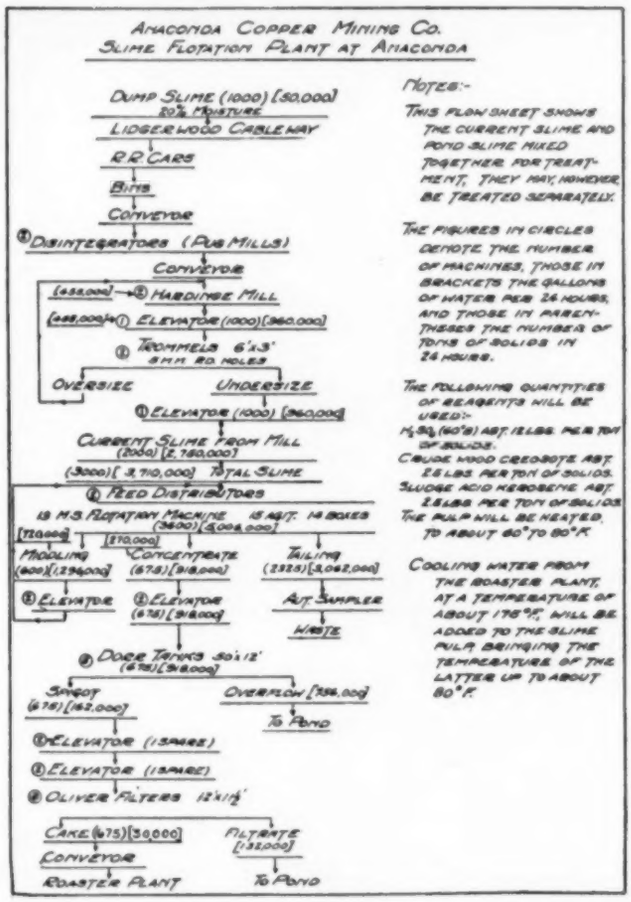

ANACONDA COPPER MINING CO.
SLIME FLOTATION PLANT AT ANACONDA
DUMP SLIME (1000) [50,000]
20% MOISTURE
LIDGERWOOD CABLEWAY
R.R. CARS
BINS
CONVEYOR
DISINTEGRATORS (PUG MILLS)
CONVEYOR
HARDINGE MILL
ELEVATOR (1000) [360,000]
TROMMELS 6'x3'
5MM RD. HOLES
OVERSIZE
UNDERSIZE
ELEVATOR (1000) [360,000]
CURRENT SLIME FROM MILL
(2000) [2,160,000]
TOTAL SLIME
FEED DISTRIBUTORS
18 M.S. FLOTATION MACHINE (3600) [4,000,000]
15 AGIT. 14 BOXES
MIDDLING
CONCENTRATE
TAILING
ELEVATOR
ELEVATOR
AUT. SAMPLER
WASTE
DORR TANKS 50'x12'
SPIGOT
OVERFLOW [336,000]
TO POND
ELEVATOR (13 BUCKET)
ELEVATOR (13 BUCKET)
OLIVER FILTERS 12'x14'
CAKE [30,000]
FILTRATE
CONVEYOR
ROASTER PLANT
TO POND
NOTES:-
THIS FLOW SHEET SHOWS THE CURRENT SLIME AND POND SLIME MIXED TOGETHER FOR TREATMENT. THEY MAY, HOWEVER, BE TREATED SEPARATELY.
THE FIGURES IN CIRCLES DENOTE THE NUMBER OF MACHINES, THOSE IN BRACKETS THE GALLONS OF WATER PER 24 HOURS, AND THOSE IN PARENTHESES THE NUMBER OF TONS OF SOLIDS IN 24 HOURS.
THE FOLLOWING QUANTITIES OF REAGENTS WILL BE USED:-
H_2SO_4 (60°B) ABT. 12 LBS. PER TON OF SOLIDS.
CRUDE WOOD CREOSOTE ABT. 2 LBS. PER TON OF SOLIDS.
SLUDGE ACID KEROSENE ABT. 2 LBS. PER TON OF SOLIDS.
THE PULP WILL BE HEATED TO ABOUT 60° TO 80° F.
COOLING WATER FROM THE ROASTER PLANT, AT A TEMPERATURE OF ABOUT 175° F., WILL BE ADDED TO THE SLIME PULP, BRINGING THE TEMPERATURE OF THE LATTER UP TO ABOUT 80° F.

FIG. 2—FLOW SHEET OF SLIME FLOTATION PLANT AT ANACONDA, MONT.

per cent solids, and the spigot averages 60 per cent solids. The spigot product is further dewatered on Oliver filters, making a cake containing about 15 per cent moisture, which is discharged to a belt conveyor running to the roaster plant.

Meeting of the Arizona Section of the American Institute of Mining Engineers

A meeting of the Arizona Section of the American Institute of Mining Engineers was held at Globe, Ariz., on Monday and Tuesday, Feb. 21 and 22.

There were two technical sessions, in the morning and evening of Monday. Monday afternoon was spent in visiting the Old Dominion mine and reduction works. Tuesday morning a visit was paid to the International Smelter and the mine and mill of the Miami Copper Company, followed by luncheon at the Miami Copper Company's offices. Tuesday afternoon was spent in an excursion to the mine and mill of the Inspiration Consolidated Copper Company, and in the evening an informal banquet was held at the Dominion Hotel in Globe, at which there were present sixty-five members and guests of the Arizona Section. Tentative plans for the entertainment of the Institute at the Arizona meeting in September were discussed, but further development was left to the executive committee.

The following papers were presented at the technical sessions:

Co-operative Effort in Mining, by J. P. HODGSON. The author dealt with the methods employed by the Copper Queen Company in getting their men to pull together. A system of monthly meetings of the staff has been the cornerstone on which to build up the *esprit de corps*.

Shrinkage Stoping with Narrow Stopes and Pillars and Soft Ore, by J. G. FLYNN; Shrinkage Stoping with Wide Stopes and Pillars and Hard Ore, by ARCHIE SCOTT; Block Method of Top Slicing in Large Ore Bodies, by E. G. DEANE. These three papers dealt with various methods that have been used or are to be used in the mining of the ore bodies of the Miami Copper Company.

Experimental Ore Drawing Tests and the Inspiration Consolidated Copper Company's Method of Mining, by J. R. LEHMAN. This paper will probably prove to become very important as it records a laboratory method upon which are being based many of the estimates for the future operation of this big mine. A small-scale stope was filled with crushed ore and covered with crushed capping. The possible extractions of the crushed ore from such a shrinkage stope, were investigated with loading chutes spaced at various intervals along this model which was built to scale in every particular. The main conclusion is that the shorter the spacing between loading chutes and the smaller the charge withdrawn the greater the possible extraction of ore from the stope with a minimum of dilution by capping. The Inspiration Company expects to extract about 87 out of every 100 tons of ore broken and diluted with about 1.2 tons of capping. It will be interesting to see how time will bear out this prediction.

Cost and Per Cent of Saving of Ore in Selection of Mining Method, by C. E. ARNOLD. This paper, which is partly based on the results obtained with the miniature shrinkage stope, discussed the points which came up in these calculations at Inspiration.

Surface Equipment of the Inspiration Consolidated Copper Company, by H. KENYON BURCH. In this paper, which was illustrated by numerous lantern slides, the author gave a good idea of the Inspiration Concentrator which is considered the finest and most up-to-date plant of its kind. This paper was very complete and gave much very interesting detail. Everything used at this concentrator is probably unexcelled in the metallurgical field. All machinery was installed only after exhaustive preliminary tests. Even after the first design of the mill was settled on and much of the construction material ordered, new factors came up which caused the cancellation of orders and further testing. Much interest was aroused by the statement that of the original machinery planned for the first mill only the three traveling cranes are in the present mill. Everything is designed to be automatic as nearly as possible.

The Cottrell Installation at the Reduction Works of the International Smelting and Refining Co., Miami, by Dr. H. W. MORSE. This brief paper was of especial interest to the members of the section because they had an opportunity to see the Cottrell installation at the International smelter which treats the Inspiration and Miami concentrates.

Experiments on Leaching at Ajo, by Dr. H. W. MORSE and HENRY F. TOBLEMAN. After the one-ton testing plant had given very encouraging results and these had been used as a basis for the design of a large commercial copper-leaching plant, it was decided to make further experiments in a 40-ton testing plant. Much to the surprise of everyone the results did not check up those of the one-ton plant and after the rather serious difficulties encountered had been solved it became necessary to modify in some respects the ideas about the construction of the large permanent copper leaching plant now being designed for the treatment of the carbonate ores. About one-half of one per cent of the mill solution will be withdrawn on every cycle and run to waste after precipitation on scrap iron. This will prevent fouling of the main mill solutions. The cement copper produced will be introduced into the mill circuit to reduce some ferric iron and be conveyed into the electrolytic plant. Lead anodes have been decided upon.

History of Flotation at Inspiration, by Dr. RUDOLF GAHL. The author reported what difficulties had been encountered in the operation of the 600-ton experimental flotation plant of the Inspiration Company and how they have been solved. The fruit of this large-scale test was that no new difficulties were met with when the commercial concentrator was started, the 18th (800-ton) unit of which was taken in operation during the visit of the engineers. Dr. Gahl's paper gave many details of the development of flotation at Inspiration and of the competitive tests which were made between various types of machines. The steps which led up to the development of the Inspiration machine were recounted. Some most interesting effects of the method of grinding on the flotation were detailed, especially the fact that iron filings seem to assist the flotation to a remarkable extent. A total operating cost of a little over six cents for flotation was recorded.

Grinding Practice in Miami District, by T. B. COUNSELMAN.

These papers will be further amplified and elaborated. They will then be printed and form the basis for discussions at the meetings of the whole of the Institute in Arizona this fall.

Meeting of the Montana Section of the American Institute of Mining Engineers

The annual meeting and banquet of the Montana Section of the American Institute of Mining Engineers was held on Feb. 4, at the Silver Bow Club, Butte, Mont. There were forty-nine members and guests present. Following the dinner, a business and technical session was held.

The following officers were elected for the ensuing year: Chairman, J. L. Bruce, manager of Butte & Superior Copper Co.; vice-chairman, W. C. Siderfin, manager W. A. Clark interests in Montana; secretary-treasurer, M. H. Gidel, assistant geologist A. C. M. Co. Executive committee: N. B. Braly, superintendent of mines of North Butte Mining Co. and W. T. Burns, superintendent of Electric Refining B. & M. Reduction Works, Great Falls, Mont.

Following the banquet, a paper entitled "Present Status of Oil Prospecting in Montana," was read by Prof. D. C. Bard who is joint author of the paper with Chester Steele. Mr. Frederick Laist of the Anaconda Copper Mining Company gave a talk on the metallurgy of zinc, explaining briefly the method employed by the Anaconda Company for the treatment of complex zinc ore from the Butte district.

The secretary's report shows 177 active members in the State, an increase of seventeen over that of last year.

Bibliography on Flotation.—The bulletin of the School of Mines and Metallurgy of the University of Missouri for January, 1916, contains a bibliography on flotation, compiled by Jesse Cunningham, librarian. The general references date from 1900 up to January, 1916. There is a special section on colloids and surface tension and special sections on litigation and patents. The work was originally designed for the use of students at the above university but the information should prove very helpful to those engaged in flotation work, in aiding them to avoid repetition and to compare the results of others.

Hydrogen for Military Purposes

From the very interesting paper of Captain **Edward D. Ardery,** Corps of Engineers, U. S. Army, presented in the symposium on electrochemical war supplies before the New York Section of the American Electrochemical Society on Feb. 11, we give the following extracts to supplement the preliminary account given in our issue of March 1 (page 260).

For military purposes hydrogen finds its greatest use in inflating balloons, either captive or free. To generate the hydrogen gas readily and in sufficient quantities, recourse has been had to various processes. Probably the first method used consisted in employing iron filings and dilute sulphuric acid. Similarly, zinc may be used instead of iron. Hydrogen from zinc and sulphuric acid is purer than when iron is used. One hundred pounds of sulphuric acid and about 140 lb. of zinc give 1000 cu. ft. of hydrogen. A balloon with a capacity of 16,000 cu. ft. would thus require about two tons of these materials.

In the Russo-Japanese war the Russians used a process based on the action of aluminium on sodium hydroxide. This method presupposes an ample water supply, and has the drawback that it requires 5½ kg. of materials for every cubic meter of hydrogen produced. The apparatus consisted of sheet metal containers, each of which was partly filled with sodium hydroxide. The aluminium chips were held in a gauze drum, a portion of which rested in the liquid. From the producer the gas passed through the washer and from there to the balloon.

In the Morocco campaign, the Spanish government used a producer developed by Schuckert & Co. Instead of using aluminium, silicon was employed. At temperature of from 80 to 90 deg. C. the action of this element and sodium hydroxide is energetic. The temperature need not be attained by the use of fuel if the natural development of heat during the preparation of the hydroxide solution is utilized.

Schuckert's process is based on the reaction of metallic silicon and hot alkaline lye produced by the solution in water of solid caustic soda. Preparations for starting the generator consist merely in pulverized caustic soda being poured amid stirring into a solution vessel containing water, thus getting a solution of 90 deg. C. in temperature. By turning on a cock this solution is admitted to the generator, and silicon is added. During the formation of the gas, which lasts about 50 minutes, water is again filled into the solution vessel, and caustic soda in pieces added, which quickly dissolves with the aid of the hot hydrogen touching the sides of the solution vessel. This enables a new cycle to be commenced with only a few minutes' interruption at the end of every generating process. When the formation of gas is finished, the generator contains a solution of water-glass, a non-injurious liquid, which can be let out without special precaution. The heat arising does not exceed 110 deg. C. The apparatus, made of iron, and not being subject to chemical or mechanical destruction, is of practically unlimited durability.

The French have used ferro-silicon instead of silicon. The producing apparatus is called "silicol." Another method originated by the French is called the "hydrogenit" process. This is particularly adapted for use where an abundance of water is not available. "Hydrogenit" is a mixture of finely powdered ferro-silicon and sodium calcium oxide. It is a gray, sandy substance, which, even in a closed receptacle, burns with a large production of hydrogen. The mixture is ignited by means of a match or a small amount of ignition powder. It comes in sheet metal containers, and is said to keep indefinitely at normal temperatures. These containers are placed bodily in the producer and fired. The producer is surrounded by a water jacket, the contents of which are eventually converted into steam. Toward the end of the process the steam is shot into the chamber to accelerate the action. The gas is washed in water and then dried by passing through screens of sawdust and coke.

Calcium hydride, a substance known commercially as "hydrolith," (CaH_2), if dropped into water, evolves hydrogen rapidly.

$$CaH_2 + 2H_2O = Ca(OH)_2 + 4H.$$

The objection to it is its excessive cost. A sodium base may be used instead of calcium, but great care is necessary to prevent ignition of the hydrogen by the heat of the chemical reaction. "Hydrone" is another substance that requires only the addition of water to produce hydrogen.

A German corporation has perfected the old method of producing hydrogen by passing steam over red-hot iron filings. The steam is dissociated, the oxygen combining with the hot iron to form black oxide of iron (Fe_3O_4), leaving hydrogen free. The iron is then regenerated by blowing over the iron, hot water-gas containing a large percentage of carbon monoxide. The black oxide gives up oxygen and becomes heated. Oxygen combines with CO to make CO_2. The process may be made continuous by using two ovens.

In manufacturing nitrogen and oxygen from the air, low temperatures are employed, but these temperatures are not low enough to effect the separation of hydrogen from water gas. Water gas consists of H, CO and N. It also contains a comparatively small percentage of CO_2, which is first eliminated by passing the gas over caustic potash. The gas thus purified is compressed to about 30 atmospheres, and cooled to a temperature in the neighborhood of the boiling point of oxygen, say 200 deg. C. The liquefiable constituents are the CO and N, whose critical temperatures are respectively 136 and 146 C. In this process the water gas used contains about 50 per cent hydrogen, and so displays, on the whole, the physical properties of hydrogen. When allowed to escape from an open valve at the temperature of its surroundings, hydrogen does not cool, but rises in temperature. Thus the method applied in the liquifaction of air is not applicable for cooling water gas. Liquid air is therefore resorted to, the requisite degree of cold being obtained by allowing it to evaporate. In spite of the efforts to eliminate CO_2 and water vapor, traces of these bodies pass into the separating apparatus and are deposited there in solid form, ultimately obstructing it after the lapse of a certain time. By having duplicate plants one can be worked while the other is brought back into working shape by heating it and blowing gas through it.

The signal corps of the U. S. Army has made experiments with a view to obtaining hydrogen by refrigerating illuminating gas.

A method invented by two Dutch engineers is used both in Germany and in Russia. This process uses the gas produced by the fractional distillation of crude oil and tar. The gas is passed through a layer of hot coke, whereby the hydrocarbons break up with ultimate liberation of hydrogen. The product delivered contains from 2 to 3 per cent of CO, which is removed by subsequently treating with hot sodium oxide. Oil-gas, crude oil, petroleum by-products, tar, benzol or benzine may be employed in the same process. Charcoal can be used instead of coke. The oil is introduced as a spray at the top of the producer, having been previously heated. The coke is brought to a white heat by a hot air blast. As the oil eventually cools the coke, production is intermittent.

Our army installed a plant at Fort Omaha, Neb., for generating hydrogen by the electrolysis of water. Thirty cells were used, and 1500 amperes of direct current were passed through the cells in series. The voltage varied from 85 to 120, depending on the internal resistance of the cells.

The filter press system of Sürth came into use about eight years ago. The Sürth system is used extensively by Germany for military purposes.

Hydrogen gas from oil-gas is about 98.4 per cent pure, with a specific gravity of 0.087 to 0.092. From water gas the hydrogen is 97 to 97½ per cent pure; but if this be passed over gas soda lime the resulting gas contains as its only impurity 0.6 to 0.8 per cent of nitrogen. A percentage of 97 to 97½ hydrogen corresponds to a density of 0.094, while when the percentage of hydrogen is raised to 99.2 or 99.4, the density falls to 0.077. Schuckert's metallic silicon process gives hydrogen at least 99 per cent pure, and free of poisonous or injurious admixtures. The Sürth electrolytic process gives hydrogen 99.8 per cent pure.

Stationary plants, usually providing for generation on a large scale, must necessarily be designed along lines more economical than for portable plants. Stationary plants would find use at aeronautic establishments, army centers, and at points where gas is generated to be compressed into cylinders for shipment. Stationary plants may have capacities for generating 300 cubic meters and upwards per hour. The smaller sizes would probably weigh about 4000 kg. net, or 5500 kg. packed for ocean shipment; the larger sizes, 9500 kg. net, and 12,000 kg. gross; no piece weighing over 2000 kg. The electrolytic plant installed at Fort Omaha in 1908 had a capacity of 3000 cu. ft. per hour. To follow an army's movements portable plants are necessary. These should permit of being mounted on cars or wagons. Some plants can be set up on shipboard, some on three or fewer railroad cars and others on wagons. The capacity of portable plants varies from 9 cu. ft. per hour to 1600 cubic meters per hour.

The weights of portable plants depend, of course, on the capacity and type of plant. Schuckert's generator cars weigh about 2000 kg. each, and the scrubber cars about 1700 to 2100 kg.

In comparing the relative cost of portable plants and stationary plants distributing by means of steel tubes, consideration should be given to the cost of the tubes, their weight to be transported, and the cost of compressing the gas.

For transporting in campaign, hydrogen may be absorbed by some chemical substance dissolving it or giving with it a combination capable of restoring it easily and rapidly whenever wished; hydrolith and hydrone being in this class. Or, the gas may be compressed in steel tubes. Some French tubes are about 4 meters long, 270 millimeters interior diameter, and 9 millimeters thick. Other dimensions are used at sea and in the colonies. In order to avoid explosions, tubes have been tried with diameters of 45 to 400 mm.

The U. S. service employs cylinders about 7 ft. long, and 5½ in. in diameter; and about 4 ft. long and 8½ in. in diameter. They are made of cold-drawn seamless steel tubing.

The weight of steel cylinders is less than the weight of the iron and sulphuric acid necessary to produce an equal volume of hydrogen. The weight of these tubes does not exceed 100 lb. each. In the French service each wagon carrying tubes weighs 3000 kg. for about every 15 kg. of gas transported—about 200 times the weight of the hydrogen. They contain 200 litres of gas at 133 kg. pressure; equivalent to about 25 cu. m. at atmospheric pressure. The German flasks hold about 36 litres of gas at a pressure of 130 atmospheres, which corresponds to about 5 cu. m. of balloon space. Some American flasks contain 100 and 200 cu. ft. In some cases compression is done at from 150 to 200 atmospheres (2200 to 2940 lb.). Pressures as low as 700 lb. have been used to prevent explosion. Tanks used in welding or cutting are charged to about 100 or 150 lb. In the U. S. service the tubes are tested with hydraulic pressure up to about 5000 lb., and are charged to about one-half of the pressure used in testing. All cylinders have a safety outlet blowing at 3500 lb. The 7-ft. x 5½-in. tubes have a capacity of about 1 cu. ft., and are ordinarily charged to 120 atmospheres.

For German conditions it has apparently been found that the best method of bringing gas to the balloons is not to bring the producer to the front, but to send forward the hydrogen in steel flasks. The flasks are transported in caissons, 20 to each vehicle, and it is so arranged that six caissons can be coupled together when the balloon is to be filled. The French have some wagons that carry six tubes. The transportation of hydrogen in steel tubes is quite an old practice. The English have used tubes since 1882; the Italians, since 1887.

The Germans fill a 600-cubic meter balloon from 120 flasks in about 20 minutes. Using oil gas for producing hydrogen requires one or two hours to fire up. According to the size of the plant being used Schuckert's metallic silicon process allows of a full production of hydrogen to be reached in from 10 to 45 minutes from the time the command is given. Other processes require different periods of time before hydrogen becomes available for inflation, so the compressed gas in flasks has a considerable advantage as far as the time factor is concerned. Their two principal objections are the danger of explosion and the dead weight to be carried.

A pipe line for carrying hydrogen is in successful operation in Germany. The line is 4½ kilometers long, and can supply 1000 cu. m. of gas daily. This requires a pressure of 1000 mm. (water column.) It discharges into a storage tank. The joints of the pipe are welded autogeneously for most of the length, unions being installed at long intervals.

The cost of production of hydrogen varies, of course, with the size of the plant, market and labor conditions, and the process used. Some of the *alleged* costs per cubic meter of hydrogen, according to the process used are: ferrosilicon, 20c., hydrogenit 32c., hydrolith 100c., steam and hot iron filings 3c, distillation of crude oil and tar 3½c., water gas 25c., old method of iron and sulphuric acid 25c.; the calcium hydride method 5c. per cu. ft., silicon and caustic soda 6c per cu. ft. By electrolysis 1500 amperes produce 23 cu. ft. of hydrogen and 11½ cu. ft. of oxygen per cell per hour.

Notes on Chemical and Metallurgical Engineering in Great Britain

(From Our London Correspondent)

The General Outlook

All prophecy is dangerous at the present time. At any time it is subject to unforeseen happenings. Today the unrealized factors may be more numerous than the cheerful optimists in Flanders imagine. At any rate they can scarcely be as dire as some distressed pessimists at home announce. So your correspondent, who resumes his letters after an interval of three months, will leave prophecy to the wise and confine his comments to actual tendencies and actual happenings. Under the latter category we are in travail with a very big distribution of labor, involving extensive re-groupings, large withdrawals of men, the initiation of un-

skilled labor, male and female, into the zealously guarded mysteries of machine minding, and the growing numbers of women employed in occupations previously regarded as purely masculine. No one pretends that the way is smooth or that minor situations do not need tactful handling. Generally we are working longer hours, and the artisan class being highly paid, there is no real pressure resulting from the high level of food prices.

Industrially we are virtually marking time in all save those industries which contribute to the equipment of the navy and the army. We cannot reasonably look at a time like the present for great mental activity, for new inventions, let alone for large outputs of commodities other than those concerned with the war. The growth of one tendency must not pass unchronicled. Month by month there is a powerful movement (destined to become still more powerful) making for a complete imperial industrial independence. Partly through an apathetic lack of imagination, partly through an obsolete—albeit economically sound—banking system, and partly through past years of laziness, we have in the past sedulously fostered an industrial dependence upon very many enemy products. Inability to barter coal, or cotton goods, or colonial produce for these during the war has indicated to us how near we were, and how ignorant we were of our nearness, to a species of industrial servitude. It is fairly certain that the movement to foster our imperial industrial independence of certain manufacturing nations will be one of the earliest modifications which we shall experience after the war. We shall, of course, have to blend the prescriptions of those who will tender their advice. Some will speak of a tariff as the magician's wand which will of itself conjure into being new highly specialized industries. Others will claim that through scientific and technical education alone our prospect of industrial success will come. Both will, of course, be important contributory forces. No wise blending of these two forces will do all we want. Psychologically, too, we must engender an industrial patriotism on which we now depend for victory.

We know now that military conflict will only be succeeded by an intense commercial warfare. The stress of competition will be much more severe than anything we have known in the past. In the present war we have forged new weapons, devised new safeguards, and regrouped very large masses of workers. New products, efficiency of output and intelligent direction are the factors on which we must depend. The most hopeful augury for the future is that we are weighing its problems and meditating on trade strategy in a way quite foreign to us in the old slothful days.

For the time, the commercial supremacy of the world will have passed to your side of the Atlantic. With it, only slightly changed in form, there will have passed all our old problems. As we regain part of our old supremacy we shall have again to meet all the old foes of our own household with new forces. Speculation, though, as to these is really too remote for contemplation to-day.

The Manufacture of Optical Glass

The movement alluded to above—i.e., that of industrial independence in Germany—is well exemplified in Dr. Rosenhain's three Cantor lectures before the Royal Society of Arts upon this subject. It was more than pleasing to be told that considerable grants had been made to the National Physical Laboratory and to other bodies for the purpose of research upon this subject.

Optical glass, Dr. Rosenhain stated, might simply be defined as better than glass, purer, and possessing various properties for special optical purposes. The variety of purposes introduced difficulties; spectacles, telescopes, photographic lenses, etc., required different properties, apart from certain fundamental requirements. As regards transparency, the best glasses were nearly perfect. They should also be colorless, but that claim might be overdone; the greenish color due to the presence of traces of iron could be reduced by adding manganese, but at the expense of transparency, because the glass then absorbed both blue and green rays. The color was not necessarily due to impurities, moreover; certain dense flints looked yellow, especially when heated, because they absorbed the ultra-violet, and the absorption bands shifted in the hot glass. The transparency was also impeded by solid impurities (bits of clay, etc.), and by gas bubbles which were continually liberated from the carbonates and nitrates of the melting glass mixture; big bubbles carried small bubbles away, but a mist of very fine bubbles was a very troublesome feature. The fused glass finally formed a very complex solution of great viscosity and stiffness, which yet remained in a state of flow (which might become a serious matter in big telescope lenses) and inclined to crystallize. This tendency to crystallize limited the admissible properties of salts, which favored devitrification. Even a block of window glass cooled in the furnace at a very slow rate might devitrify—a specimen exhibited was full of wallastonite—and heavy barium glasses had to be chilled lest crystallization set in.

In dealing with the optical properties of various kinds of glass, Dr. Rosenhain emphasized the importance of refraction and dispersion. He said that owing to the dispersion each color gave, so to say, a different picture, and white light gave a picture with colored fringes. By combining different lenses of different glasses, achromatism could be secured, but it was only approximate and for parts of the spectrum, and a residual spectrum always remained. For the old glasses the plotting of the dispersive powers against the refractive index practically yielded a straight line. The new glasses allowed the combination of any refractive index and any dispersion. The old glasses were essentially alkali-calcium silicates (crown) or lead glasses (flint); the new glasses contained also phosphates, borates, etc., and many hitherto unused metallic oxides; their refractive index rose above 1.7, the density above 4, and barium crown glass (of high index and low dispersion) could be substituted for flint glass. A little color did not matter for gun sights and some telescopes; spherical aberration, coma, and other defects, which the Jena glasses also allowed to be corrected, were more serious.

Dr. Rosenhain's second lecture was in part historical and in part a description of different processes. The third, however, dealt with the possible improvements of the rather primitive method of optical glass making. By heroic efforts the output in this country has been raised to twenty times what it had been before the war. But that was not on business lines, and to carry the optical glass industry on after the war would require either direct or indirect state subsidy, or, better, combined research of scientists and manufacturers. The task was difficult, for Dr. Rosenhain doubted whether the optical glass industry was really profitable anywhere. At Jena, Schott and Genossen co-operated with Zeiss in instrument making and in the manufacture of chemical ware; those branches yielded the profit, while even Jena thermometer glass was being supplied at a loss, he believed. Examining the present process in detail, he pointed out that it was slow and laborious, and the yield low. To hasten the melting (which took up to four days) by higher temperatures was not advisable, if feasible. As the temperature rose, the erosion of the

pot by the glass increased. The fireclay itself would not stand more than 1800 deg. C., and the heat could only reach the mixture through the walls and the dome of the pot. The door and cover, or dome, could not be removed, because that would expose the mixture to contamination by gases (reducing gas was dangerous to flints in particular), dust, and crumbling particles dropping from the furnace arch. Electric furnaces and crucibles might be tried. Wire resistances did not yield temperatures above 1400 deg.; with spiral carbon resistance the required 1600 deg. or 1800 deg. C. might easily be obtained, but not for pots 30 in. in diameter; induction furnaces (of the Kjellin type) were unsuitable, because efficient stirring in the annular groove would hardly be possible; in arc furnaces the heat was too concentrated, though something might be done with the Stassano radiation arc, if contamination by the ash of the carbons were not too dangerous. Arc resistance furnaces (in which the arc was formed between the carbons and the slag floating on the fused metal) might answer, if something akin to the protecting slag layer could be found. It might also be possible to float the crucible on a molten, or place it in that bath of glass or slag, heating the bath by the arc resistance method. Electric glass furnaces were already used to a certain extent, but a satisfactory type had yet to be evolved.

The pot was a greater difficulty than the furnace. There was the whole group of refractory rare earths; there were silundum, carborundum and other new substances, and, lastly, tungsten and molybdenum were being put to uses not dreamed of a few years ago. Supposing they found a suitable pot material. They could then stir to complete homogeneity even near the pot walls, which they dared not do now, lest the sticky, stringy glass adhering to the walls should contaminate the bulk; they could pour the glass, get a yield of perhaps 80 per cent, instead of 20 or 30, and re-use the pot or crucible; that was the key to the problem.

The Metallurgy of Pistons for Diesel Engines

At the November meeting of the Diesel Engine Users' Association, Mr. J. M. Ferguson laid stress on the great importance of using metal of the special quality necessary for pistons of Diesel engines. Mr. P. H. Smith remarked that the fundamental cause of cracks in Diesel engine pistons was a highly heated core trying to expand but being restricted in so doing by a comparatively cold and very stiff ring of metal surrounding it. In cooling, after the engine had been shut down, the core did not quite resume its original unstrained condition. This action being progressive with alternate heating and cooling, the stresses became higher until fracture occurred. Some makers were endeavoring to find a cast iron for pistons which would not "grow" on repeated heating and cooling. Such an iron was very pure, high in manganese and low in silicon, and being mainly of Swedish origin was therefore practically unobtainable at the present time. He then described his arrangement of a renewable core in the piston head, which he considered would provide a solution to the trouble of cracking. This is made in two parts, so as to reduce stresses to a minimum in the core as well as in the piston. The core proper, or inner portion, is fixed on to a recess in the piston head by a gas-tight joint, well removed from the region of highest temperature, and is surrounded by a separate ring. The core is free to expand laterally and longitudinally, and the ring is similarly unrestricted. To reduce any tendency to crack in the remaining portion of the piston head, the recess which contains the core is stepped, the depths of the steps gradually increasing, and the top edge of the recess is sufficiently removed from the hottest region to avoid cracking or fraying out.

Synopsis of Recent Chemical and Metallurgical Literature

Gold and Silver

Segregation in Gold Buillion.—Accuracy in the assay of gold bars practically free from silver but containing base metals other than copper, as for example cyanide bullion, is the subject of a paper presented by JAMES H. HANCE, of Iowa City, Iowa, in the February *Bulletin* of the A. I. M. E. The author reports the results of an investigation begun while in the service of the Government as assistant assayer of the Salt Lake Assay Office. Variations in assays are tabulated and shown also in diagram and curves. The results are summarized as follows:

1. Drillings taken near the edge are extremely variable, but generally assay higher than the dips, a fact which may be due to early solidification and an accompanying segregation in those portions of the bar of metals of the highest freezing points, taking into account mutual solubilities and alloying tendencies. In a platinum-gold alloy this same characteristic is very apparent, but is due, as Mathey observes, to the liquidation of the platinum.

2. The center of the bar, top and bottom, is usually lower in value than the dips. As suggested in the author's paper this may be due to a late solidification in these and similar points, which results in a higher percentage of base metals with low freezing points. Mutual solubilities may be a factor here, also, but the substance in large excess (gold) does not concentrate toward the center or last place of solidification as does quartz in the cooling of a quartz-rich magma.

3. In a majority of cases the top drillings assay higher than do those of the bottom, and the same is true of the dips. In order to balance the personal equation the method of weighing assays was reversed so that the weigher who received the top samples at first, later received the bottom samples. For this reason samples were frequently exchanged in weighing. The same variations, however, continued to be apparent.

An extreme range in the dip assays is in some cases due to the presence of impurities introduced while the dips are being taken. Where a scorifier is used to catch part of the stream of metal, small pieces of clay might easily be caught and retained in the bullion granules.

4. Drillings taken at any one point along these profiles vary as widely in assay value as drillings of any other points similarly chosen. Also, maxima and minima points are as apt to occur near the center of the bar as near the ends. From this standpoint the corner drillings seem no better nor worse than drillings from nearer the center.

5. The liquation in some cyanide bars is similar to that which takes place when the rare metals are present in appreciable amounts, but in the former instance it seems to be due to the presence of certain base metals.

Attention is again called to the fact that these difficulties are not encountered where a small amount of silver is present, as the presence of this latter metal seems to diminish segregation. Lessened segregation is probably due to the solvent properties of silver toward certain base metals, such as lead, zinc, etc. Silver may exert an appreciable influence on other metals or non-metals also. Where 90 or 100 points of silver were known to be present in the bar, no dip samples were taken, and the drillings rarely failed to check well within the limits allowed. This is doubtless due to the fact that silver or silver-gold alloy in which the silver content is nearly 10 per cent or better, is a good solvent for the metals or non-metals causing segregation. Pure or silver-free gold is not a good solvent for these sub-

stances, and hence does not prevent the formation of an irregular bar.

This suggests one way of overcoming the difficulty of assaying cyanide bullion, although it does not solve the problem. If to all such cyanide bars known to contain little or no silver, a small amount of that metal be added in melting, a uniform bar after melt could easily be obtained and its fineness accurately determined. From the fineness thus obtained the inquartation silver could be subtracted, leaving the silver fineness of the original bar. As such gold bars are alloyed with silver for refining operations, the above suggested operation would mean a little additional work for the compueters only, but this extra work would be more than offset by the increased accuracy of the gold assay.

Refining Cyanide Precipitate at the Liberty Bell Mill.—Owing to wide variations in composition of Liberty Bell precipitate it has been necessary to discard wet methods of refining and substitute the more exact method of flux calculation. The method is described by A. J. WERNIG, mill superintendent for the company, in a paper to be presented at the forthcoming fall meeting of the A. I. M. E. Table I gives an idea of the range in composition and grade of the precipitates.

TABLE I.—RANGE OF COMPOSITION OF RAW PRECIPITATES

	Per Cent
Gold and silver	25.0 to 75
Zinc	18.0 to 30
Lead	0.5 to 52
Copper	0.5 to 20
Silica	1.0 to 5
Calcium oxide	4.0 to 8
Sulphur	0.5 to 8

The present method of flux refining has been arrived at through a vast amount of experiment. In general, it embodies the principle of the addition of an oxidizer, and the proper proportionment of fluxes to carry off the oxidized impurities as metallic bases in a fluid slag.

A rather wide experience in the melting of precipitates has shown that the various impurities of precipitates are oxidized and driven into the slag in a definite order. Zinc tends to oxidize first, and the resulting zinc oxide will combine with the acid radical of the flux and therefore enter the slag. As in blast-furnace practice, the zinc tends to render slags infusible; and for this reason borax glass is always used in a greater amount than silica to furnish the acid radical for the slag. Borax glass greatly increases the fusibility of zinky slags.

Sulphur tends to oxidize second, and if an alkaline oxide is present in the melt, alkaline sulphate is formed, which is rather easily fusible. This sulphate is not soluble in the slag, and, being lighter, rises to the surface of the melt, forming the well-known sulphate "cover." The sulphate "cover" is nearly always quite sure, so that after any melt the melter may easily separate it from the slag, and, by weighing and computing its sulphur content, obtain a close check on the analysis of the precipitate. This cover is either Na_2SO_4 or K_2SO_4 depending on the alkaline oxide present. (The sulphate cover is an intensely interesting material to the chemist. Many unsuspected elements are known to concentrate therein. In the Liberty Bell material, Mo, As, Sb, Te, Se and V have been detected.) Where precipitate is melted without oxidizers, sulphur generally makes itself known by the formation of matte—a very undesirable by-product.

After all sulphur is oxidized, lead will oxidize, and the resulting lead oxide enters the slag proper. It is well known that lead oxide combines with silica in nearly all proportions under the influence of heat, and that the resulting lead silicates are easily fusible between rather wide limits. For this reason more silica may be used in the melt when much lead is present, and for the same reason the amount of borax glass may be diminished.

After lead, copper will oxidize to Cu_2O and combine with the acid radical of the slag. The color of such slags is red. Where an excessive amount of oxidizer is present, copper will oxidize to CuO, and slag containing this oxide is green.

This selective oxidation is most clearly evident in the order of oxidation between copper and lead. It is practically impossible to drive copper into the slag as long as metallic lead is present in the bullion. Here quantitative separations between lead and copper are easily obtained.

Graphite crucibles have a marked reducing action on lead slags. No matter how rapid the melting, or how fast the resulting slag is removed from the crucible, if much lead is present, some will be reduced to metal. In such cases it is practically impossible, in direct melting, to slag copper, even though oxidizers are added far beyond the calculated requirement.

Where melts are conducted in clay or clay-lined graphite crucibles, this reducing action is of course avoided, and as a result copper will be found to enter the slag as easily as lead, though not until all lead is oxidized. Hence, in melting precipitate in graphite crucibles no attempt is made to slag copper. If a desirable grade of bullion can not be made unless copper is slagged, the melter will then, of course, use clay or clay-lined crucibles.

The common oxidizing fluxes are manganese dioxide, potassium and sodium nitrates. The first is costly on account of the comparatively low quantity of available oxygen. It also requires extra weight of acid flux to retain Na_2O in the slag. Sodium nitrate is highly recommended on account of its high available oxygen, and in the crude form imported from Chile it is cheap and satisfactory.

Table II gives the common impurities of the precipitate and the common fluxes. Columns 2, 3 and 4 give the weight of oxygen that the substance will evolve or combine with, in per cent of original weight of substance. Column 5 shows weight of manganese dioxide required to oxidize a unit weight of the substance on the same line in column 1. In columns 6 and 7 are given weights of nitrates required to oxidize a unit weight of substance. Columns 8 and 9 give the weight in pounds

TABLE II.—FLUX TABLE

Substance	Molecular Weight	Per Cent Oxygen			1 Lb. Substance Requires, Pounds					
		Acid	Base	Available	MnO_2	KNO_3	$NaNO_3$	K_2CO_3	Na_2CO_3	
Cu'	63	....	25.4	12.7	1.40	1.07	0.91			
Cu'	63	....	12.7	....	0.70	0.54	0.46			
Pb	207	....	7.7	....	0.43	0.33	0.28			
Zn	65	....	24.6	....	1.35	1.03	0.87			
Fe	56	....	28.5	....	1.57	1.20	1.01			
S	32	....	....	....	8.30	6.30	5.30	4.30	3.30	
SiO_2	60	53.4								
CaO	56	....	28.5							
MnO_2	88	....	18.2	18.2						
$NaNO_3$	85	....	9.4	28.2						
KNO_3	101	....	7.8	23.8						
Na_2CO_3	106	....	15.1							
K_2CO_3	128	....	12.5							
Na_2O	62	....	25.8							
K_2O	94	....	17.0							
$Na_2B_4O_7$	202	47.7	7.9							
Mixture of 2 parts borax glass and 1 part silica	.....	49.6	5.3	....	....	....	....	....	....	39.0 per cent available acid oxygen.
Mixture of 1 part borax glass and 1 part silica	.....	51.1	3.2	....	....	....	....	....	....	44.7 per cent available acid oxygen.
Mixture of 3 parts borax glass and 2 parts silica	.....	50.0	4.8	....	....	....	....	....	....	40.4 per cent available acid oxygen.
Column No.	1	2	3	4	5	6	7	8	9	10

of the carbonates required to form sulphates with 1 lb. of sulphur which has been oxidized to SO_3. These carbonates are used only when MnO_2 is the sole oxidizer.

The author presents two cases of flux calculation, one of which is given in Table III. The type of slag made, two of acid oxygen to one of basic oxygen, is the result of experience. This slag is most easily fusible and least corrosive on the crucible. It runs low in precious metal, having been made repeatedly as low as $20 per ton. While the slags vary widely in composition they all conform to the type above mentioned.

An important feature of the refining process is the sintering of the fluxed precipitate. Sintering is done in cast-iron pans in an iron muffle. The temperature is gradually raised to red heat and practically all the chemical reactions are completed. The sinter is in excellent condition for melting, giving no trouble from dusting and greatly increasing the capacity of crucibles.

Slags are stored and smelted in a small blast furnace once a year, with brick charges made from ash obtained by burning old mill launders and tanks. Considerable scrap copper also is smelted. Any matte made in smelting precipitate is controlled by running the furnace under stronger oxidizing conditions, thus driving the metals into bullion and slag.

TABLE III—FLUX CALCULATION

Data and Explanatory	Pounds				
	Oxygen		$NaNO_3$	Borax Glass	Silica
	Acid	Base			
(References apply to Table II) assume 100 lb. of precipitate					
Zinc 20.5 lb.					
20.5 × 0.87 (See Col. 7, opposite Zn) =	.....	.....	17.90		
20.5 × 0.246 (See Col. 3, opposite Zn) =	.....	5.04			
Lead 38.8 lb.					
38.8 × 0.28 (See Col. 7, opposite Pb) =	.....	.....	10.90		
38.8 × 0.077 (See Col. 3, opposite Pb) =	.....	3.00			
CaO 2.0 lb.					
2.0 × 0.285 (See Col. 3 opposite CaO) =	.....	0.57			
SiO_2 1.4 lb.					
1.4 × 0.534 (See Col. 2, opposite SiO_2) =	0.75				
Borax Glass (as it is desirable to maintain a ratio of borax to silica of 2 to 1 in the slag it is convenient to add here the proportionate amount of borax to balance silica in the precipitate. In this case the silica is low and this correction could readily be omitted on this particular precipitate, but as it is necessary to correct for borax here when silica is high the correction for silica is carried through for form. Hence 2 × 1.4 = 2.80 lb. borax	.....	.....	.....	2.80	
2.80 × 0.079 (See Col. 3, opposite $Na_2B_4O_7$) =	.....	0.22			
2.80 × 0.477 (See Col. 2, opposite $Na_2B_4O_7$) =	1.34				
The total pounds of $NaNO_3$ added is	.....	.....	(28.80)		
As this places extra basic oxygen in the slag as Na_2O we have: 28.80 × 0.094 (See Col. 3, opposite $NaNO_3$) =	.....	2.71			
Total acid and basic oxygen	(2.09)	(11.54)			
The 2.09 lb. acid oxygen will balance ½ (2.09) = 1.05 lb. base oxygen. This leaves 11.54 − 1.05 = 10.50 lb base oxygen to be satisfied, or 21.0 lb. extra acid oxygen to be added. Using the mixture of 2 borax and 1 silica to supply this acid oxygen, we have 21 ÷ 0.39 (See Col. 10, opposite Mix. 2 B. G. to 1 SiO_2) or 54 lb. of mixture. This is:					
36 lb. borax glass	.....	.....	.....	36.0	
18 lb. silica	.....	.....	.....	.....	18
also					
54 × 0.496 (See Col. 2, opposite Mix. 2 B.G. to 1 SiO_2) =	26.80				
54 × 0.053 (See Col. 3, opposite Mix. 2 B.G. to 1 SiO_2) =	.....	2.86			
Grand totals of acid and basic oxygen or a ratio of 2 to 1 approx.	23.89	14.50			
Sulphur—As all sulphur goes into the "cover" as well as the niter used to oxidize it we have: 1.2 × 5.30 (See Col. 7, opposite) =	.....	.....	6.37		
Grand totals of fluxes to be used	.....	.....	35.17	38.80	18.0

The melter made up the flux by parts as:

	Parts
$NaNO_3$	35
Borax	39
Silica	18
Total	92

Copper

Grades of Coal Permissible for Reverberatory Smelting.—At the recent sessions of the second Pan-American Scientific Congress, C. R. KUZELL, metallurgist for the Anaconda Copper Mining Co., discussed coal-dust firing of reverberatory furnaces. He explained that the grade of coal that can be successfully used for this work is not fixed by close limits, and that unless there is something detrimental in the ash that would make it difficult to handle when it forms accretions in the furnaces or flues, it may be said that any good coal and many poor grades may be used. The accompanying analyses show the types of coal used at various plants.

The former classification of reverberatory coals into "long-flame" and "short-flame" coals seems to have no meaning in the combustion of coal dust in the long reverberatory furnaces of to-day, because the length of the flame can be controlled by the damper, coal feeders and burners. Physical characteristics that would make a coal unsuited for grate firing are not objectionable in the new system. Consequently it is possible to use in the form of powdered fuel a much greater variety of coal than it was possible to burn satisfactorily on grates.

The ash analyses for a few of these coals are available and are given here:

One can readily see that the ash of coals Nos. 3, 4 and 5, if agglomerated into an accretion of the composition shown, would make a sticky mass at moderately high temperatures. This is exactly what happens in the hotter part of the reverberatory-furnace flue, but the removal of these sticky masses is only a matter of minor importance. That which falls on the slag bath in the furnace is all the more easily fused into the slag because of this slagging tendency of the ash itself. Small additions of lime rock flux rabbled into the scum at the slag-skimming bay a few times a day is sufficient to complete the fusion. One must know the origin of the ash of coal No. 2 to understand its behavior. It is due to three things, at least: A large quantity (about 8 per cent) of "sulphur balls," which are hard, heavy concretions of iron pyrite (FeS_2); a seam of "bone" interbanded with the coal—the "bone" being carboniferous alumnium silicate which, when free from carbon, is an extremely refractory "kaolin;" and the mineral substance of the plants from which the coal was formed—in this case probably a very silicious substance. At any rate, sources Nos. 2 and 3 give to the ash a highly refractory portion of low specific gravity,

COAL USED FOR COAL-DUST FIRING

Proximate Analysis					Heating Value B.t.u. per Lb.		Ultimate Analysis						
Coal Number	Moisture	Volatile Matter	Fixed Carbon	Ash	Dry	Wet	H_2O	H	C	N	Ash	O	S
1	4.3	34.7	55.4	9.5	13,500	12,850		Not available					1.3
2	7.0	24.5	46.3	22.1	9,910	9,210	7.0	3.8	31.7	0.6	20.3	12.3	4.3
3	6.5	40.9	43.1	9.5	12,490	11,690	6.5	4.3	65.5	0.9	9.7	12.4	0.7
4	10.5	39.2	42.9	7.4	13,080	12,070		Not available					
5	6.6	33.7	47.8	12.0	12,570	11,870		Not available					
6	9.0	35.5	43.4	12.7	11,500	10,500		Not available					
7	13.3	32.9	38.5	15.3	10,853	9,660		Not available					

Coal Number	SiO_2	FeO	Al_2O_3	CaO
2	48.3	14.0	35.1	0.5
3	48.1	8.2	21.1	8.2
4	56.6	5.1	21.6	11.0
5	54.3	7.2	19.5	9.1

and source No. 1 gives a heavy iron sulphide of low melting point. It is very probable that the latter drops unburned into the furnace bath, because of the neutral or slightly reducing atmosphere in the furnace. The former collects on the slag and in the flue as a light fluffy deposit which has been found not to interfere at all with the calorific efficiency of the furnace.

Tungsten and Molybdenum

Tungsten and Molybdenum as Substitutes for Platinum.—In an elaborate paper in the January *Bulletin* of the American Institute of Mining Engineers, Mr. FRANK A. FAHRENWALD gives the results of an extended research on substitutes for platinum in the arts and sciences.

The substitute desired must satisfy the following conditions: Its melting point must be high, at least well above 1200 deg. C. It must not be affected by those chemical compounds formed in its application, nor should it oxidize at a soldering temperature. It must possess sufficient strength to resist stresses tending to change its form while in place, and at the same time be sufficiently pliable to be worked to the desired shape. Its coefficient of expansion must be low, in order that desired dimensions may be easily produced in the finished product. (This factor is important, since the range through which this material is manipulated is often more than 1000 deg. C.) It should unite readily with gold, silver and similar metals, and their solders. Its cost of production should be low, as compared with that of platinum.

The experimental work resolved itself into three parts, each being marked by a different method of attack, necessitated by limitations encountered as the work progressed under previously adopted methods.

The first part consisted of experiments in binary combinations of those of the metals which it was feasible to consider, and the melting points of which lay within the limits of ordinary fusion methods. The results of these experiments, performed as indicated therein, lead to the conclusion that metals or alloys of metals outside of the precious-metal groups, are unsuitable as substitutes for platinum.

The gold and silver alloys of palladium have been found to be excellent substitutes for platinum in its softer forms, and while not so chemically resistant, fill all requirements where conditions are not too rigid.

The second part develops the fact that except in two respects, pure ductile tungsten, and, to a lesser degree, molybdenum, meet all of the specifications of a practical substitute for platinum and its alloys. These two defects are its ease of oxidation, and the difficulty with which it can be soldered; and they have been overcome by coating with a precious metal or alloy, the resulting material being in many ways far superior to platinum or its alloys. This material has met with instant demand, is in many cases replacing the best platinum-iridium alloys, and permits the performance of work which has been impossible with the materials hitherto available.

The third part describes the theoretical and practical considerations involved in the manufacture of wrought tungsten and molybdenum, and gives results of the proper application of a similar method in the laboratory production of their alloys.

Wrought tungsten and molybdenum were produced on a laboratory scale, but no success attended the attempted production of alloys of tungsten with gold and palladium; while on the other hand, the alloys of the tungsten-molybdenum series were produced in wrought form. These operations were governed entirely by metallographic control, and their success suggests the possible application of a similar method in a treatment of such metals as iridium, tantalum, rhodium, osmium, etc., in combination with each other, or with tungsten or molybdenum, which may result in the production of alloys possessing properties far superior to those of any material now available.

Recent Chemical and Metallurgical Patents

Iron and Steel

Production of Ferrosilicon in the Electric Furnace.—A furnace for the production of ferrosilicon which is designed for the utilization of lower-grade raw materials than generally used is patented by HERBERT C. HARRISON of Niagara Falls, N. Y. (assigned to Electro Metallurgical Company of Niagara Falls, N. Y.) It is a combined combustion and electrical furnace, a cross-section of which is shown in Fig. 1. The furnace has twelve electrodes extending down into the hearth (1), as shown, the connections and adjustments needing no explanation. The roof (3) has manholes (10) with gas-tight closures (11); supported directly above the roof-opening (4) is a stack combustion chamber

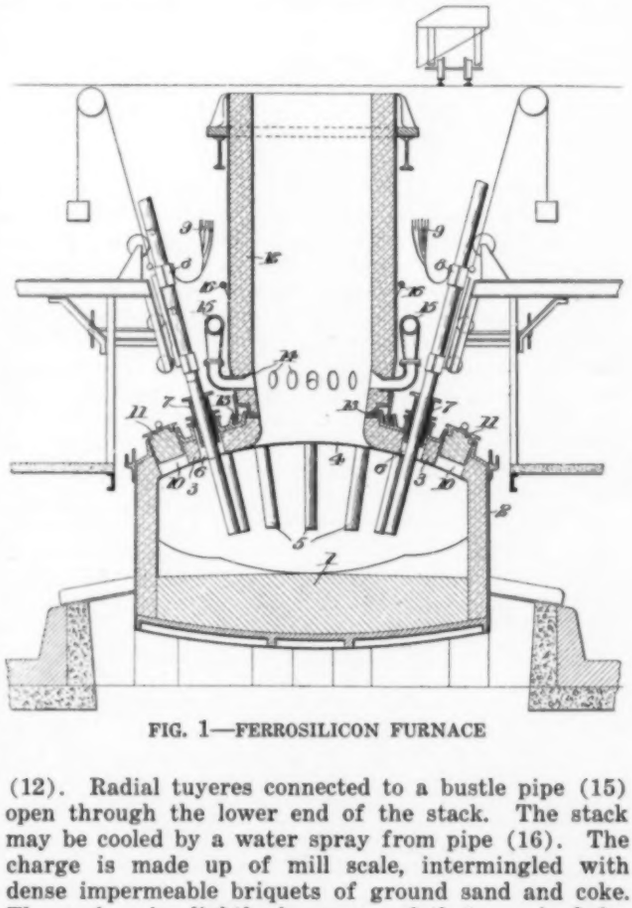


FIG. 1—FERROSILICON FURNACE

(12). Radial tuyeres connected to a bustle pipe (15) open through the lower end of the stack. The stack may be cooled by a water spray from pipe (16). The charge is made up of mill scale, intermingled with dense impermeable briquets of ground sand and coke. The carbon is slightly in excess of that required for the reduction of the silica. A charge consists of approximately 169 parts of mill scale, 269 parts sand and 139 parts coke (80 per cent carbon). The preheating of the charge is effected in the portion of the column above the tuyeres by the combustion of the carbon monoxide rising from below. The charge is introduced in the form of briquets and a temperature of about 2000 deg. C. is needed in the final zone where the silicon is reduced. Air is introduced through the tuyeres to effect combustion of the excess carbon monoxide not used in reducing iron. The process is operated continuously. (1,171,719, Feb. 15, 1916.)

Iron and Steel Direct from Ore.—A process for the production of iron and steel direct from ore by the use of fuel oil as reducing agent is patented by HERBERT HAAS of San Francisco, Cal. The process is carried out in a tilting furnace having a row of tuyere pipes on one of its sides. The tuyere pipes are also above the bath in the furnace, which consists of iron and iron oxide kept at about 1600 deg. C. Atomizers are placed in the tuyere pipes, and the oil, previously vaporized by subjecting it to a high pressure, is forced through the molten iron oxide. Firing of the furnace is not interrupted, because the heat balance shows that if proper precautions are not observed the bath will freeze, owing to the heat used to break up the hydrocarbons into carbon and hydrogen and to reduce the iron oxide. However, by limiting the amount of oil to a relatively small quantity compared with the large body of molten material it is claimed that freezing is prevented. After the iron oxides have been reduced a portion of the iron may be removed to another furnace and finished into steel. To reduce the fuel consumption and facilitate the smelting, it is desirable to maintain a bed of molten iron always in the hearth, and remove only a portion of this iron or steel, and on top of the remaining bath charge fresh iron ore and fluxes. (1,156,775, Oct. 12, 1915.)

Gas Washer.—A gas washer for blast furnace gases in which the gases are made to impinge on the surface of a series of pools of water is patented by THOMAS MCDONALD, of Youngstown, Ohio. The arrangement of the washers is shown in Fig. 2. The gases enter at 2, and are first sprayed from pipes 3. They are then led down and impinge on the surface of the water in pockets 9 and 10. They then pass up and over baffle 22 and follow the course shown through the succeeding baffles. The descending spaces are made smaller than the ascending to prevent picking up of particles already deposited. The water flows from one pocket to the next in a steady stream from left to right, thus removing the scum as fast as it is formed. Bells

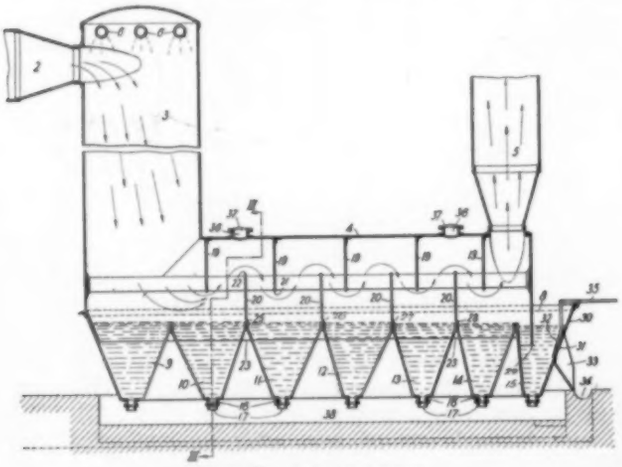
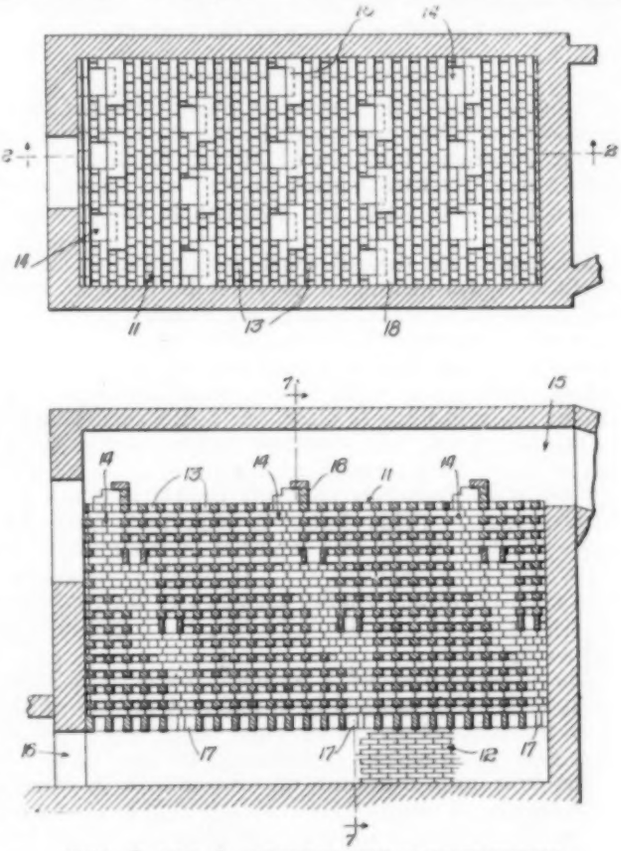


FIG. 2—GAS WASHER

16 are provided for cleaning out the pockets. The pockets are made successively smaller, as they receive less and less deposited particles as the gases pass through. (1,167,909, Jan. 11, 1916.)

Regenerator for Furnaces.—A novel scheme for constructing regenerators in order to prevent clogging up from flue dust in the gases is patented by FRANK ORTH, of Indiana Harbor, Indiana. The idea can best be explained by reference to one form of construction as shown in Figs. 3 and 4. Fig. 3 is a section-plan view, and Fig. 4 is a longitudinal cross-section of a generator constructed according to these principles. As the gases enter at 15, they pass through ordinary sized openings 11, and larger passageways 14. Baffle plates 18 aid in a more even distribution of the gases. As the gases pass through these large passageways 14 (which are constructed sloping in the direction shown to make



FIGS. 3 AND 4—REGENERATOR CONSTRUCTION

the passageway approximately at an angle of 90 degrees with the incoming gases, whose tendency is to go forward and downward), they can find openings or longitudinal ducts on each level of brick so that there is provided a surface distribution area which is a great many times greater than if the gases simply entered at the top and went straight through to the bottom.

In practice with the old system it has been the experience that the upper sections become clogged up much quicker than the lower sections, and consequently the regenerator had to be thrown out of operation while it was cleaned. In the present method, it does not matter whether the upper layers become clogged or not as the large passageways conduct the gases down to the succeeding layers until suitable openings are encountered. The ability of the gases to pass horizontally along each layer from the large passageways is a distinct feature. The operation of the regenerator may be continued even when all the small openings are clogged, as the large passageways will still conduct the gases. The period of time before cleaning is necessary is thus very much prolonged, and a consequent saving in time and labor is effected. Many other arrangements may be made to carry out substantially the same idea, such as arranging larger intermediate longitudinal passageways, providing larger openings in the top than in the body of the regenerator, or other changes. (1,165,340, Dec. 21, 1915.)

Gaseous Reducing Agents in Iron Production.—A novel process of producing iron from iron ores by the use of gaseous reducing agents, such as hydrogen, natural gas, methane, ethylenes, or the like, in the electric furnace is patented by EMIL BRUCE PRATT, of Lake-

wood, Ohio. No special design of electric furnace is necessary. Pure hydrogen from the electrolysis of water may be used or other gaseous hydrocarbons as mentioned above. These gaseous hydrocarbons are decomposed at temperatures below the melting point of iron ore, and the process is based on the affinity of hydrogen for oxygen. It is claimed that no silicon need enter the iron if the temperature of the bath is kept even and not far above the melting point of iron, as there is no silicon in the fuel. By increasing the temperature or adding alloys, silicon may be added to the metal. No blast is necessary and finely pulverized ores may be used. It has been found desirable to preheat the reducing agent, especially when a hydrocarbon is used.

The claims made for the process are that it provides a means of controlling both silicon and carbon and may be used when electrical energy is cheap and solid carbon fuel expensive. (1,167,016, Jan. 4, 1916.)

Iron and Sulphur from Pyrite.—An electric furnace process of treating sulphides of iron directly for the production of iron and sulphur, is patented by Mr. LEWIS T. WRIGHT of London, England. Pyrite or other suitable sulphides of iron, either fresh material or material previously heated in some other furnace, is charged into a tilting electric melting furnace, having a single carbon electrode in the top and metallic plate electrode at the bottom. The top is closed and the sulphur vapors are conducted away through an opening in the top to a condenser. The charge is heated to about 3000 deg. C. when practically all the sulphur will distill off, leaving a bath of pure molten iron, which is tapped. Slags may also be used when desired. (1,164,049, Dec. 14, 1915.)

Copper

Hydrometallurgy of Copper.—A process for the hydroelectric treatment of ores is patented by ROBERT RHEA GOODRICH of Tucson, Ariz. In this process, which is shown diagrammatically in Fig. 5, the copper solution resulting from leaching an ore is run from tank 5 to a heater 7, where it is heated to about 50 deg. C. From the heater the solution flows to electrolytic vats 11 of step No. 1. The solution is circulated through these vats by pump 13 and is returned from the last vat to heater tank 7. Part of the solution overflows from the last vat to tank 16, from which it goes to single cell 20 of step No. 2. The diagram explains the subsequent steps. The cells are all connected in series so that the same current flows through all cells. The electrodes of the separate cells are connected in parallel. The copper content of the electrolyte in the separate steps is maintained constant and in geometrical ratio, and the current density is made to correspond. For example: If the copper solution in tank 5 contains 6 per cent copper, the current may be maintained to deposit enough copper so that the electrolyte will contain 1.5 per cent copper in step 1. If the current density is 20 amp. per square foot then it is made one-fourth, one-third or one-half that amount in step 2, according to the proportion desired. In this case one-fourth was used so that one-fourth the number of cells is used in step 2 as in step 1 and one-fourth the current density. The copper content in step 2 will be made 0.375 per cent.

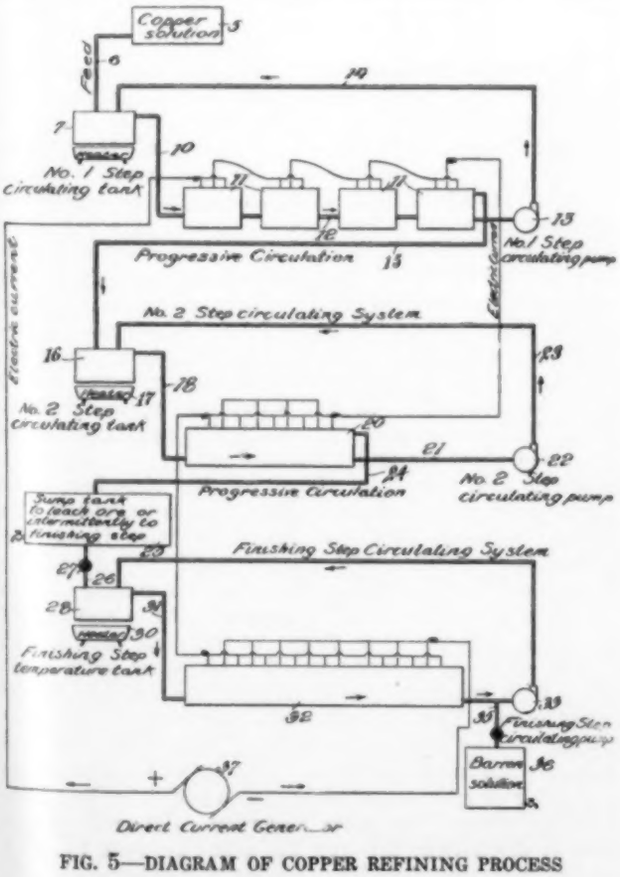


FIG. 5—DIAGRAM OF COPPER REFINING PROCESS

It is claimed that by endeavoring to maintain a constant copper content in the electrolyte through each step and maintaining this content and the depositing conditions in geometrical ratio that the conditions of ordinary electrolytic copper refining are most easily attained. (1,171,782, Feb. 15, 1916.)

Tin

Detinning Process.—A process of detinning based upon previous processes using dry chlorine has been patented by GEORGE O. SEWARD and the late FRANZ VON KÜGELGEN of East Orange, N. J. (assigned to Columbia-Knickerbocker Trust Co., New York). This is a reissue of patent No. 851,946, April 30, 1907, and is based upon patent No. 915,029, March 9, 1909, a short description of which was given in this journal April, 1909, page 169. This latter patent aimed to treat tin scrap by placing it in a vessel and introducing dry chlorine, which attacked the tin, forming stannic chloride, which condensed on the sides of the vessel. It was necessary to control the temperature within very narrow limits, and this was done by limiting the amount of chlorine introduced and applying external cooling by water. In the original of this reissued patent it was proposed to limit the amount of tin scrap and effect temperature control in this manner. The present patent proposes to introduce a considerable excess of chlorine to carry away the excess heat generated. It is desirable to introduce the chlorine as cool as possible. With a chamber of 40 cu. ft. capacity a charge of 150 lb. of tin scrap has given successful results. (14,070 and 14,071, Feb. 15, 1916.)

Zinc

Electric Zinc Furnace.—An electric furnace for producing metals which are vaporized and condensed, such as lead and zinc, is patented by ALOIS HELFENSTEIN of Vienna, Austria-Hungary. The furnace is designed to overcome the causes of dusting such as in electric zinc furnaces, by separating the gaseous products before reduction takes place. Water and carbonic acid, also hydrogen and hydrocarbons, cause the liquid zinc to precipitate as dust (blue powder) through partial reoxidation and combination with the metal vapor. A cross-section of one style of the furnace is shown in

Fig. 6. An upper electrode C_1 forms the heating element and current is conducted down through the charge to the lower electrode C_2. The charge in the columns h_1 and h_2 is preheated by carbon monoxide from pipes p_1 and p_2, which is burned by admitting air at s_1 and s_2. As the charge descends the gases given off are conducted away through passages i_1 and i_2, any zinc vapor-

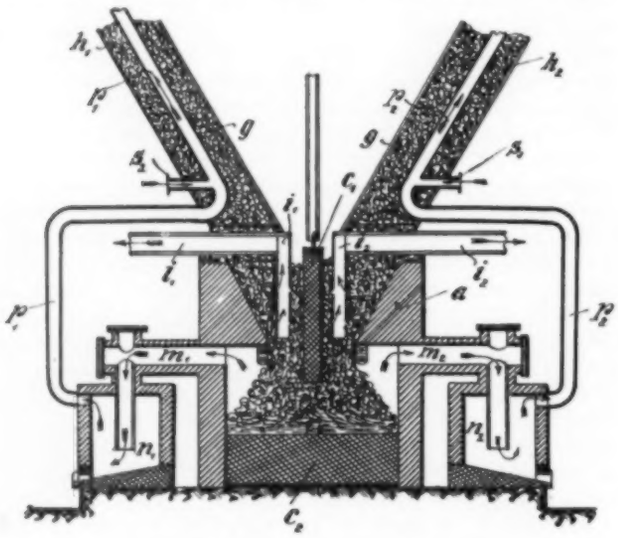


FIG. 6—ELECTRIC ZINC FURNACE

ized and tending to rise is caught by the descending charge, which acts as a sort of filter. When the charge reaches the reduction zone it is reduced and metallic vapors pass off through passages m_1 and m_2 to condensing chamber n_1 and n_2. Any carbon monoxide going over passes through pipes p_1 and p_2, as stated before, and is used to preheat the descending charge. (1,167,998, Jan. 11, 1916.)

Oxygen and Hydrogen

Oxygen and Hydrogen Generating System.—An electrolytic system for the generation of oxygen and hydrogen is patented by George Halter of New York, N. Y. (assigned to Davis-Bournonville Company, New York). The system consists of an electrolytic cell with pressure regulator and purifier and automatic controlling means for maintaining the level of liquid in the cell constant. The cell consists of a rectangular iron tank divided into two compartments by an iron partition. The tank itself and the partition serve as the cathode. In each compartment is an anode in the shape of a long, rectangular, hollow basket-shaped unit, made of perforated sheet metal, electroplated as a protection against rusting. The perforations are in the form of slits, about 1 15/16 in. long by 1/16 in. wide, arranged in staggered rows. The perforations allow the inner as well as the outer surface of the anode to be used. Surrounding the anode is a diaphragm of asbestos, which fits over the anode like a sack, with extending ribs at the bottom to keep it from touching the anode. The aim is to provide large anode and cathode surface. Suitable spaces are arranged above for conducting away the oxygen and hydrogen. Upon leaving the cell the oxygen and hydrogen are conducted through separate pipes to the bottom of a pressure regulator, where the gases bubble up through water under a common head for both gases, the gases being kept separate by going through separate chambers. In passing through the pressure regulator shown in Fig. 7 the gases bubble up from inlet pipe 65, through 67 to space 69, where the pressure forces the liquid down until the gas can escape under wall 70. In this space 69 an incandescent electric wire is placed which ignites any impurities, forcing down the piston 84, which operates to shut down the plant. The use of the common hydrostatic head for both gases in the regulator equalizes the pressure on both sides of the diaphragm in the cell. By suitable

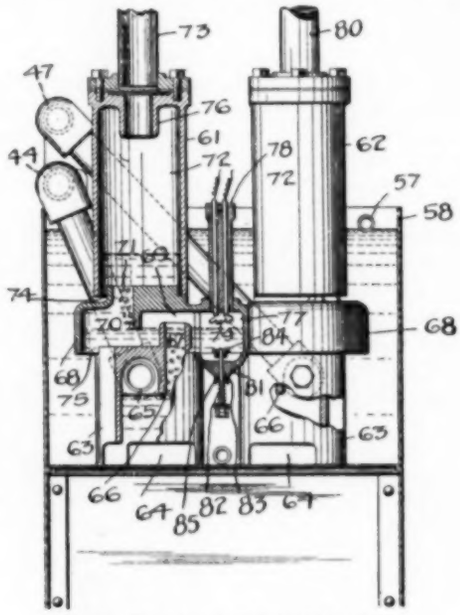


FIG. 7—PRESSURE REGULATOR

overflow arrangements in connection with the regulator a constant level of liquid is maintained in the electrolytic cell. (1,172,886-7, Feb. 22, 1916.) Another patent which was applied for before the above describes a cell much the same except that the anode is made up of wires. (1,172,855, Feb. 22, 1916.)

Nitric Acid

Fixation of Atmospheric Nitrogen.—An apparatus for producing nitric acid from air is patented by William T. Hoofnagle of Glen Ridge, N. J. (assigned to Electrochemical Products Company of New York, N. Y.). In this process, the air first passes through a drier, from which it is conducted to an expansion chamber, where it is kept under reduced pressure. The expansion chamber is connected to a reaction chamber, in which the electrical discharge takes place. The object of the expansion chamber is to prevent excessive agitation of the air when it is sucked into the reaction chamber. The reaction chamber is connected to an absorber, which in turn is connected to a vacuum pump which runs continuously. In the operation of the process, which is intermittent, automatically operated valves open and allow air under reduced pressure to enter the reaction chamber from the expansion chamber. The valves then close and electricity is passed through at a high voltage and very low current by using inner electrodes of glass filled with mercury and outer electrodes of non-oxidizable metal. The reaction chamber is in the form of a cylinder with rounded bottom and having an inner core the same shape as the outer shell. The inside electrode is made up of a series of glass tubes filled with mercury placed around the outside of the inner core. The outside metal electrode is similarly placed around the inside wall of the outer shell and opposite the inside electrode. The outside electrode has a number of ribs spaced at intervals and extending horizontally toward the inner electrode. Alternating current is discharged through the space between the electrodes, the ribs forming annular discharging or con-

centrating points and partly rectifying the current. Due to the low current the heating effect is small. The necessary wattage is obtained by the high voltage. The current is applied to the air in the reaction chamber as long as the pressure continues to fall, due to the decreasing volume resulting from the combination of the oxygen and nitrogen. At the moment when the unstable oxides tend to break up into NO, causing an increase in volume and pressure, the application of the current is automatically shut off by an electrical mechanism controlled by the pressure gage. The electrically controlled valves then open, and the treated air and gases are drawn into the absorber. (1,169,824, Feb. 1, 1916.)

Oil

Electrostatic Separation of Oil and Water.—In treating oil emulsions by electricity, by passing them between high potential electrodes, short circuits may occur due to the formation of chains of globules between the electrodes. A process designed to overcome this difficulty is patented by FRANK W. PEEK, JR., of Schenectady, N. Y. (assigned to General Electric Company). It can best be understood by reference to the illustration, Fig. 8. The oil from a receiving tank 1 passes through valve 8 into the hollow tube 9, which forms one electrode and has projections as shown. The casing 2 is made of glass, porcelain or other dielectric material, and has metal electrode 7 fastened on the outside. The electrodes are connected to a high-potential transformer furnishing a high potential and creating an electrostatic field between the electrodes. The oil passes down through hollow electrode 9 into the bottom of the container and rises up, oil being withdrawn through pipe 5. As the oil passes between the electrodes it is at first attracted to the inner electrode which has a smaller surface than the glass and consequently exists in a more intense field. The action can be clearly seen through the glass and a spark passes to each drop before it touches the electrode. When it touches it is quickly repelled to the glass where it adheres and slowly drips down, being withdrawn at 6. By passing oil containing water through this apparatus with a potential of 15,000 volts, it is claimed that the disruptive voltage was increased from 23 to 52 kilovolts using a standard gap at constant spacing for comparison. (1,170,184 Feb. 1, 1916.)

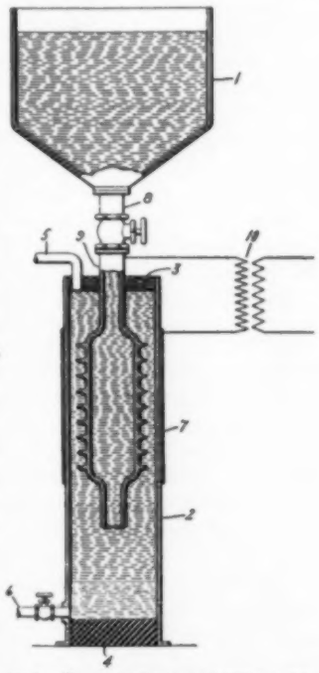


FIG. 8—ELECTROSTATIC SEPARATOR

Recovery of Metals from Waste Oils.—A patent has been issued to MATHEW E. ROTHBERG of Grafton, Pa. (assigned to Falk Co. of Pittsburgh), on a process of treatment of waste oils to recover the metals they contain either as compounds or mechanically suspended. Oils used to protect metallic coatings from oxidation, occurring as by-products, and containing some metals probably dissolved through the breaking up of the oils by heat, are first cleaned of mechanically suspended particles, then treated with a concentrated mineral acid in a suitable receptacle. The acid and oil are separated by gravity and the metals recovered from the solution. The acid used depends on the metals to be dissolved and its specific gravity must be such that an emulsion of the oil and acid is not formed. (1,170,342 Feb. 1, 1916.)

The Western Metallurgical Field

End of Brief Labor Strike at Leadville

Incipient labor troubles made their appearance on Feb. 26 at the Arkansas Valley smelter of the A. S. & R. Company, at Leadville, Col., but were ended without other effect than to reduce the scale of operations for about two weeks. Dissension apparently was spread among the workmen by a few employed on the charging floor who demanded an increase in wages of 50 cents per day, with the result that about 600 men quit work and left the plant. All who engaged in the strike were foreigners, and the majority Austrians. There was no violence and the company placed no guards on its property. Owing to the fact that Colorado is "dry" there was no drinking or carousing, and to this is attributed in large measure the lack of violent demonstrations.

The State Industrial Commission sent representatives to the district and held conferences with the strikers, explaining that under the present laws of Colorado the strike was called in violation of the provision of prior notice, and that no efforts at adjustment could be made until the men had returned to work. Interest among the strikers gradually subsided and the men began to return to work. At one time all smelting operations were practically suspended; later two furnaces were put in blast and at the present time five are in use as before the strike. With the exception of a shortage of labor, due to the fact that some men left the district, conditions are again about normal. The company has made no promises regarding a change in the scale of wages, which will remain the same as established last fall when a 5 per cent increase was granted.

New Cyanide Mill for Oatman, Ariz.

The United Eastern Company, one of the largest of the new concerns to enter the new Oatman district in Arizona, has finally decided to erect a cyanide mill. Conflicting reports regarding this mill have been current for some time, but these are now settled by an official announcement. Grading is in progress for the structure which will be erected on a site immediately below the new three-compartment shaft that is being sunk. The initial capacity will be 200 tons per day, and the design will be such that additional capacity can be secured by constructing new units.

Metallurgical and Chemical Developments in Utah

The investigation of electrolytic reduction of zinc concentrates, which has been conducted by the Daly-Judge Mining Company, of Park City, Utah, has resulted in the decision to erect a plant of this type in the immediate future. The company is one of the largest in the Park City district and has been a producer of zinc concentrates which have been shipped to smelters. Power for the new plant will be obtained from the Snake Creek hydroelectric development which has been acquired by the Daly-Judge company. The proposed reduction plant will be built in units, the first of which will have a capacity of about 35 tons per day.

The Garfield Chemical & Manufacturing Company is a newly organized concern that will erect and operate a plant for the production of sulphuric acid in the vicinity of Salt Lake City, Utah. Presumably this is the

plant which the American Smelting & Refining Company is reported to have had in mind for some time past. It is reported that the first unit of 100 tons daily capacity will be in operation by Aug. 1.

The new chloridizing-roasting and leaching plant of the Tintic Milling Company, at Silver City in the Tintic district has been completed in part and is now in operation. Two of the three Holt-Dern roasters are in use, and when the third furnace of this type and the Christensen furnace also are in operation, the capacity will be about 300 tons per day. The process is the same as was used at Park City by the same interests, and which has been previously described in this journal.

Continued Expansion in the Joplin District

Operators in the Joplin district are continuing to build new concentrating plants in order to take advantage of the high prices prevailing for lead and zinc concentrates. On local authority it is estimated that about half a million dollars will be spent on new concentrating mills in the Missouri-Kansas-Oklahoma district between now and May 1. Three of the largest concentrating mills in the Joplin district are contracted for, two of which will be built at Webb City and will have a daily capacity of 500 tons each. Two 400-ton mills are to be built in the North Carterville district, and numerous other mills of lesser capacities have been ordered.

The latter part of February witnessed the highest price ever paid in Joplin for galena concentrates, when $89 per ton was paid for 80 per cent lead content. The previous high price was $88.50 in 1907. Zinc concentrates continue to bring a high price, though not as high in proportion to the price for spelter as in the case of lead concentrates.

Mineral Production of Canada in 1915

From the preliminary report on the mineral production of Canada for 1915 by John McLeish, of the Department of Mines, we note that the production was the highest ever recorded, due to the demand for metals created by the war. In Table I we give the estimated quantity and value of the metallic products, and in Table II the increase or decrease in quantity and value compared with 1914.

It will be observed that there was an increased production of all metals except silver. Ontario is the largest gold-producing province, yielding 44 per cent of the total Canadian production. The 1915 output of gold from this province showed an increase of 51 per cent over that of 1914. The Hollinger and Acme mines in the Porcupine district contributed about one-half the Ontario gold output and the Dome mine nearly one-fifth.

TABLE I

Mineral Production of Canada, 1915

Product METALLIC	Quantity	Value
Antimony, pounds	961,040	$192,208
Cobalt, metallic, pounds	211,610 }	502,388
Cobalt, oxide, pounds	379,219 }	
Nickel, metallic, pounds	55,325 }	42,193
Nickel, oxide, pounds	200,032 }	
Copper, value at 17-275 cents per pound, pounds	102,612,486	17,726,307
Gold, ounces	916,076	18,936,971
Iron, pig, from Canadian ore, tons	158,598	1,740,808
Iron ore, sold for export, tons	93,444	187,682
Lead, value at 5-60 cents per pound, pounds	45,377,065	2,541,116
Molybdenite, pounds	28,600	28,460
Nickel, value at 30 cents per pound, pounds	68,077,823	20,423,348
Silver, value at 49-684 cents per ounce, ounces	28,401,735	14,088,397
Zinc, ore, tons	15,553	636,204
Total		77,046,082

TABLE II

Increase or Decrease in Principal Products, 1915

Principal Products	Increase (+) or Decrease (—) in Quantity	Per Cent	Increase (+) or Decrease (—) in Value	Per Cent
Copper, pounds	+26,876,526	35.49	+$7,424,701	72.07
Gold, ounces	+ 142,898	18.48	+ 2,953,964	18.48
Pig iron, tons	+ 130,555	16.67	+ 1,589,963	15.90
Lead, pounds	+ 9,039,300	24.88	+ 914,548	56.19
Nickel, pounds	+22,559,886	49.56	+ 6,767,967	49.56
Silver, ounces	— 48,086	0.17	— 1,505,234	9.65
Total metallic			+17,659,463	29.73

Company Reports

The net profit from mining and milling operations of the *Portland Gold Mining Company*, Cripple Creek district, Colorado, for the year 1915, amounted to $783,-191, of which $388,475 came from the mills at Victor and Colorado City. The latter plant, where high-grade ore is roasted before cyaniding, was run about to capacity and made a fair profit, handling 55,339 tons of $24 ore. The Victor low-grade mill is reported to have had its banner year for tonnage treated and profits secured, treating 213,122 tons of ore of average value of $3,033. At the Independence mill, which was acquired from Stratton's Independence, Ltd., on July 1, flotation has been adopted for the treatment of low-grade ore. The ultimate capacity will be 1000 tons per day. About one-quarter of this capacity is now available and the remodeling of the balance of the plant is proceeding rapidly. The Victor mill also is to be changed into a flotation plant of similar capacity. In order to meet a deficiency in the workmen's compensation act, which does not provide compensation for the first three weeks of disability, the Portland company has inaugurated a compensation fund to which each employee contributes 1 per cent of his monthly wages and the company a like amount. This fund pays an indemnity of half wages for sickness or injury during the time not covered by the state act. The Portland company also organized with the Vindicator company the Direct Hospital Association which has converted the old Gold Coin Club in Victor into a modern hospital for the benefit of employees. They contribute $1.25 per month for which they receive medical and surgical attention and hospital facilities. Other mining companies in the district own stock in the Hospital Association.

The report of the *Braden Copper Company*, under date of Dec. 1, 1915, contains an extended statement by Mr. Pope Yeatman, consulting engineer, regarding the present conditions and future prospects of the property in Chile. The developed tonnage has been increased from 10,074,616 tons of 2.85 per cent copper ore in 1911 to 113,694,880 tons of 2.84 per cent on Jan. 1, 1916. Up to Oct. 31, 1915, the ore extracted amounted to 3,204,484 dry tons, averaging 2.25 per cent copper. The capacity of the concentration plant will be increased to 4500 tons per day. The introduction of flotation raised the recovery from 65 per cent to over 77 per cent, and it is anticipated that 80 per cent recovery ultimately will be realized. A sulphuric acid plant is in operation to supply acid needed for flotation and leaching. The smelting process has given more trouble than any other part of the work on account of the difficulty of smelting the fine concentrates. This has been largely overcome by the use of nodulizing furnaces that make a suitable product for feeding the blast furnaces. The following is a summary for the year November, 1914, October, 1915:

Tons of dry ore milled	1,106,426
Average copper assay	2.6[illegible]
Percentage saved in mill	74.9[illegible]
Ratio of concentration	11.7[illegible]
Percentage copper in concentrates	17.6[illegible]
Percentage saved in smelter	94.4[illegible]
Tons of standard copper produced	16,366,78[illegible]

The average cost per pound of standard copper for the year was 8.78 cents. The future cost is estimated at 6.5 cents, based on increasing capacity to 10,000 tons daily.

The Application of X-Rays to Metallurgy

About one year ago it had been proven that with the proper X-ray equipment and correct time of exposure, blowholes and similar defects could be disclosed in solid metal of considerable thickness (see this journal March, 1915, page 189). Since that time the special equipment required for this kind of work has been further developed, and several factors essential to systematic and successful routine work have been established: proportion of required time of exposure to thickness of metal; dimensions of smallest air inclusion which could be detected in a given thickness of metal; regulation of electric current to obtain maximum efficiency and best results. Other points which had to be considered were to find the direction from which further progress in the application of X-rays to metallurgical work could be expected, and to establish the technique of metallo-radiography.

By ardent research work carried on in this country's finest laboratories, these problems were completely solved. The method has already been successfully applied to research work in connection with important metallurgical problems, for instance that of casting copper (see this journal Oct. 15, 1915, p. 721). If copper is cast without additions, the metal is full of pores and blowholes, mechanically unfit, and of low electric conductivity. The use of boron flux has done away entirely with the difficulty of obtaining sound copper castings of high electrical conductivity. In the difficult research problems of this work, X-ray investigations were applied with much success; stereoscopic radio-photographs of copper castings were taken, so that not only the size, but also the relative depths of the pores could be studied. Without the use of X-rays it would have been necessary to machine off layer after layer of the many sample castings. Even then the experimenter would have had to build up a mental picture of the defects in his casting on the basis of what he has seen on each of the exposed layers. From the radiographs it was possible to see all these defects at once without destroying the castings.

The value of metallo-radiographic equipment for practical testing work will be recognized as soon as the metallurgists will have had occasion to get fully acquainted with the apparatus, using it first, for a while, in pure laboratory work. The metallurgists will then find out in what way the apparatus will assist them in the solution of their manifold individual problems. The method of metallo-radiography will be of special value in examining tools, autoclaves, boilers, high-pressure cylinders, valves, saws, machine shafts, roller bearings, gear wheels, axles, cylinders and pistons of internal combustion engines, gun barrels, armor plate, submarine and aeroplane construction parts, etc.

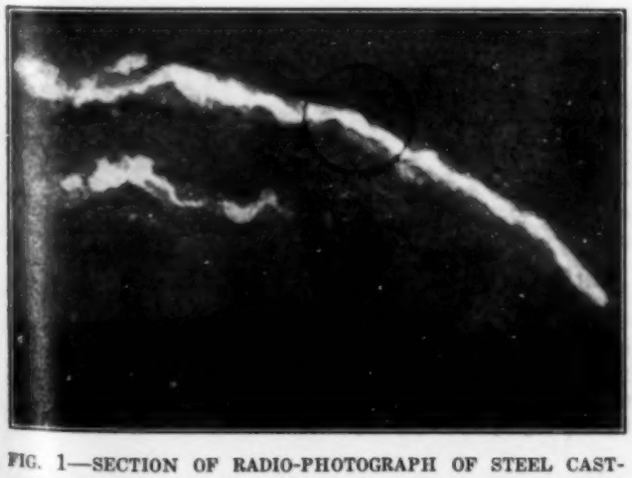


FIG. 1—SECTION OF RADIO-PHOTOGRAPH OF STEEL CASTING SHOWING FLAW IN CASTING. THE CIRCLE SHOWS WHERE A PIECE WAS LATER PUNCHED FROM THE CASTING

Research work of the most interesting kind has been carried on and is being carried on at present by means of this equipment in the diffraction of X-rays. The atoms in a crystal are arranged in a definite systematic formation and their inter-atomic distances are of the same general order of magnitude as the wave lengths of X-rays. Professor Laue of Munich regarded a crystal as a ready-made natural diffraction grating for use with X-rays, but his method is not well adapted to measuring the wave length of X-rays nor to a study of crystal structures. Prof. W. L. Bragg conceived the idea of using a crystal as a reflection grating, and his excellent method possesses the advantage that the results are easily interpreted. Using X-rays and by examining the various orders of spectra from the various crystal planes, Professor Bragg has been able to assign a definite arrangement to the atoms of a crystal. As a result of the wonderful work in X-ray spectra, the Mendelejeff table of elements is to be largely replaced by the Rutherford system of atomic numbers which is based on the fact that, if the elements are arranged in the order of their atomic weights, the "atomic numbers" are proportional to the reciprocal of the square roots of the wave lengths of the characteristic X-rays. The crystallographer is now able to measure the distances between the molecules in crystals and is able to assign a definite structure to them. The chemist now knows that, at least as far as crystals are concerned, there are no such things as molecules in the sense in which the word is ordinarily used in chemistry. The whole crystal is a big complex molecule, and the chemical formula only shows the relative amounts of each element present.

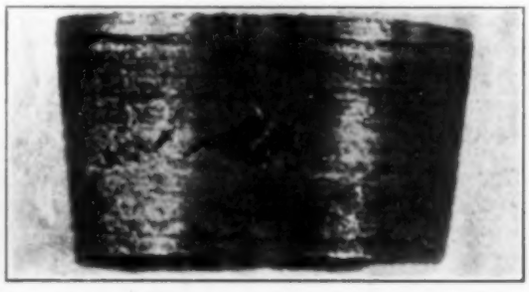


FIG. 2—PHOTOGRAPH OF EDGE OF PIECE PUNCHED FROM THE CASTING. BLOWHOLE PREVIOUSLY REVEALED IN THE RADIO-PHOTOGRAPH

It is reasonable to assume that in metals the crystal, not the molecule, is, next to the atom, the unit to be considered. It has been found that it is possible to use the characteristic X-rays as a means of identifying the various elements, so that in the measurement of the wave length of the characteristic X-rays from a substance we have an accurate method of analysis.

The points mentioned above show the big field opened for the use of X-ray equipment in metallurgical laboratories. For both practical work and research an enormous field of study is opened to the American metallurgists. Both the equipment and full details regarding correct technique, can be furnished by Mr. Herman A. Holz, 50 Church Street, New York.

Extension of Time for Alcohol Awards.—The Russian Government has extended the time of the awarding of prizes for new methods of applying alcohol to March 1, 1917, and extended the time for receiving suggestions to September. 1916.

Radioscope for Estimation of Radio-Active Bodies

In the exact estimation of radio-active bodies the need was felt for an apparatus which combined the principles of the fontactoscope and electroscope and an apparatus has been designed embodying these principles which can be used for all known methods. The apparatus which is shown in the accompanying illustration is known as the Sohocky-Willis radioscope and is constructed of heavy material and may be used with equal convenience in the field as in the laboratory for estimation of ores or fluids. The adjustable legs make it possible to place this apparatus at any desired angle. The vacuum method is used in the apparatus, the discharging chamber being constructed to withstand a high vacuum, thus making it possible to extract all the emanation from the fluid under estimation and making it possible to estimate as small an amount of fluid as 1

RADIOSCOPE

cc. The vacuum method may be combined with the boiling method.

The instrument is composed of two detachable parts, the electroscope and the discharging chamber. Amber insulation is used and instead of aluminum leaf a single conductor quartz thread is used which gives a sharply defined vision in the observation field of the microscope. The top has a capped opening with connection to the quartz thread carrier, where a condenser or voltmeter may be applied for charging. It is claimed that by proper adjustment the radioscope will accurately estimate 1/10,000 part of a microgram of radium element.

The discharge chamber is made of heavy brass and will hold a vacuum of 20 in. It has a removable bottom and screw cap for adjustment of the different electrodes which are of the round plate type. They rest on a scaled carrier pivot, which adjusts the distance between the upper and lower electrodes when the alpha ray method is used. The plate electrodes are also used when testing ores and other radio-active substances. The apparatus is supplied by the Palo Company, 80 William St., New York City.

Personal

Mr. C. G. Atwater spoke on "The By-Products from Coal Distillation" at a meeting of the Chicago section of the American Institute of Mining Engineers, held on March 9 at the Chicago Engineers' Club.

Dr. **Henry K. Benson,** professor of industrial chemistry at the University of Washington, Seattle, has been appointed director of the new Bureau of Industrial Research, the first on the Pacific Coast.

Mr. **P. P. Bourne,** formerly chief engineer of Blake & Knowles Steam Pump Works, East Cambridge, Mass., is again associated with the International Steam Pump Company in connection with special engineering work located at the main office, 115 Broadway, New York.

Mr. **Frederick G. Clapp** is in charge of the recently opened New York office of the Associated Geological Engineers, at 120 Broadway. Mr. Clapp is managing geologist of the petroleum divison of the company, whch now has offices in New York, Boston, Washington and Pittsburgh. The practice of geological engineering will be continued with especial reference to examinations and reports on oil and gas properties.

Dr. **F. W. Cunningham,** of Orange, N. J., has resigned his connection with the research and development work of the Newark plant of the General Electric Company to join the engineering research staff of the Powdered Coal Engineering & Equipment Company of Chicago, at which point he will be located after March 1. In his new connection Dr. Cunningham will considerably broaden the field of his activities.

Mr. **A. W. Dodd** has been appointed New York representative of the Granby Mining & Smelting Company, succeeding the late R. W. Conklin.

Mr. **Benjamin M. Ferguson,** chemical engineer, has taken charge of the Chicago office of the Permutit Company of New York City, specialists in water rectification problems.

Mr. **C. J. Gadd,** chief engineer of the American Iron and Steel Company, Lebanon, Pa., will deliver an illustrated lecture on the "Use of Powdered Coal in Metallurgical Processes" before the Franklin Institute on April 6, 1916.

Mr. **H. E. Howe** has become associated with Arthur D. Little, Inc., of Boston, as a field engineer. For the last eleven years he was associated with the Bausch & Lomb Optical Company. He is a chemical engineer and chairman of the Division of Industrial Chemists and Chemical Engineers of the American Chemical Society. Previous to his connection with Bausch & Lomb he was associated with the beet sugar industry in Michigan.

Mr. **R. M. Raymond,** managing director of the El Oro Mining Company, has been appointed professor of mining at Columbia University, succeeding Prof. **Henry S. Munroe,** who retired last June.

Mr. **W. F. Roberts** has been elected vice-president of the Bethlehem Steel Corporation. He has been general superintendent for several years.

Messrs. **Samuel P. Sadtler & Son,** Philadelphia, Pa., announce the removal of their office and laboratory from its former location on South Tenth Street to 210 South Thirteenth Street (New Davison Building), where they have taken the fifth floor and fitted it especially for their experimental and analytical chemical work.

Mr. **Thomas M. Skinner, Jr.,** has taken the superintendency of the Mid-Continent Chemical Co., Sand Springs, Okla., and is engaged in the erection of a new chemical plant for caustic soda, sulphuric acid and silicate of soda. Mr. Skinner was formerly connected with the Western Alkali Mfg. Co. of Green River, Wyo., and the Inyo Development Co., of Keeler, Cal. His new address is Box 351, Sands Springs, Okla.

Mr. **A. Van Zwaluwenburg,** formerly superintendent of Natividca mill, Oaxaca, Mexico, is in New York looking up flotation.

Mr. E. P. Worden, formerly of Fred M. Prescott Steam Pump Works, Milwaukee, has been appointed chief engineer of Henry R. Worthington, Harrison, N. J.

Industrial Notes

New Benzol Plant.—The Brier Hill Steel Co., Youngstown, Ohio, will erect a benzol plant in connection with the battery of by-product coke ovens authorized some time ago.

Manganese Ore in Colon.—An American syndicate has recently opened a manganese mine at Maderiga, on the Gulf of San Blas, in the Province of Colon, about 70 miles east of Colon, according to Commerce Reports. A trial shipment of 900 tons has been made to New York.

Potash.—The National Kelp Potash Company, Long Beach, Cal., will erect a plant to be in operation early in March.

Potash.—The Chemical Refinery, Ltd., will erect a plant at St. Catherines, Ontario, Canada, for the manufacture of potash and other chemicals. The company is controlled by capital from Wheeling, W. Va.

By-Product Coke Ovens and Benzol.—The H. Koppers Co. has taken contracts to erect forty-five ovens for the Camden Coke Co., Camden, N. J., and 110 ovens for the Seaboard By-Product Co., Jersey City, N. J. The ovens are to be erected with benzol recovery plants.

New Muriatic Acid Plant.—The U. S. Steel Corporation will extend its new Donora zinc smelter, the new department being for the manufacture of muriatic acid. The plant was originally constructed for spelter and sulphuric acid manufacture.

Swedish Embargo on Chemical Wood Pulp.—A recent cablegram received from the American minister at Stockholm, according to Commerce Reports, states that the Swedish Government is disposed to grant special permission for the exportation of chemical wood pulp, if it is to be used exclusively in the United States. The minister at Christiania reports that the Norwegian Government will allow unlimited exportation of the pulp to the United States.

The Quigley Furnace and Foundry Company, Springfield, Mass., has changed its name to the **Metals Production Equipment Company.** A brass rolling mill department for the production of flat brass has been added, which necessitated a more comprehensive name. The company maintains a New York office at 105 West Fortieth Street.

Corkboard Insulation.—The Armstrong Cork & Insulation Company, Pittsburgh, Pa., has issued a beautifully illustrated book describing the manufacture and uses of corkboard insulation. The gathering of the raw cork, the testing and manufacture are fully described.

Water Wheel Generators.—The Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa., has issued a special booklet describing alternating current water wheel generators. The booklet contains many interesting photographs.

Filter Press.—The Sweetland Filter Press Co., Inc., has just issued a new catalog, No. 12, describing the Sweetland self-dumping filter and metallic filter cloth.

The Grasselli Chemical Co. has placed contracts for plant extensions at its works in Ohio, Indiana and West Virginia for ore docks, and buildings at the New Jersey plant.

Research Bureau for Pacific Coast.—A Bureau of Industrial Research has been established at the University of Washington, Seattle. One fellowship of $2,000, dealing with the iron and steel industry, has been established and others are under consideration. Prof. H. K. Benson, who is director of the new laboratory, delivered an address on "The Industrial Resources and Opportunities of the Northwest" at the Seattle meeting of the American Chemical Society last September (published in our issue of Sept. 15, 1915).

New Analytical Laboratory in the South.—A laboratory has recently been opened at Columbia, S. C., in the Bank of Columbia Building, by Charles W. Rice, formerly of the F. S. Royster Guano Company, Norfolk, Va. The location at Columbia is convenient for the many industrial plants in South Carolina and vicinity. The laboratory will be a general analytical one with special attention to fertilizers, cottonseed products, foodstuffs, coal and waters. It is well equipped with modern apparatus.

Drainage Conference.—A conference was held on March 8-10 at the University of Illinois for the purpose of stimulating general and technical interest in drainage, flood protection and the reclamation of swamp and overflowed lands in Illinois. The speakers included prominent engineers and professors, and many important subjects were discussed bearing on the problem of lowlands reclamation and soil conservation.

College of City of New York Lectures.—The lecture which was to be delivered on May 5, 1916, by Dr. Thomas H. Norton, as announced in our March 1 issue, has been cancelled by orders received from the United States Department of Commerce.

The Hardinge Conical Mill Co. has moved its New York office from 50 Church Street, and is now at 120 Broadway.

Northwest Mining Convention.—A mining convention will be held in Spokane, Wash., from March 20 to 25, to be participated in by the Columbia Section, American Institute of Mining Engineers; Spokane Section, American Society of Civil Engineers; Spokane Section, American Institute of Electrical Engineers, and of the Spokane Engineering and Technical Association. Arrangements have been made for the display of ores, maps, mine models, literature and photographs.

The American Society for Testing Materials will hold its nineteenth annual meeting at Atlantic City, N. J., June 27 to July 1 inclusive, with headquarters at the Hotel Traymore.

Tungsten.—A booklet has been issued by the Mojave Tungsten Co., entitled "Tungsten." The little booklet gives some of the uses and properties of tungsten and other information as to mining conditions and output in this country. In view of the scarcity of tungsten and its increasing uses it should prove interesting. Copies may be obtained from Carlisle and Company, 74 Broadway, New York.

Quicksilver in California in 1915.—Preliminary returns to the State Mining Bureau indicate a production of 12,450 flasks of 75 lb. each. Production was but very little more than in 1914, even in face of the enormous prices prevailing, although considerable work is being pushed at present. An investigation is now under way by the State Mining Bureau on concentration and the use of oil flotation of cinnabar.

Clay Products, Cement and Lime in Canada.—The production of cement, lime, clay products, stone and other structural materials in 1914 is described in

Bulletin 383 of the Department of Mines, Mines Branch, recently issued. The report shows a great falling off in building activities of all kinds due to the war. Imports and export figures are also given which should prove interesting, especially the figures on lime and clay products, including fireclay, brick, etc.

Canadian Department of Mines in 1914.—The summary report of the Mines Branch of the Department of Mines, Canada, has been issued as Bulletin No. 346. This report contains a concise summary of the work done by the different divisions during the year. The investigations carried on are usually published as separate reports. The trip taken by Dr. A. Stansfield to Sweden to study the electric smelting of iron ores is described in bulletin 344 (reviewed in this journal Jan. 1, 1916), and the extensive work done by Dr. Herbert T. Kalmus and his assistants on electroplating with cobalt is described in bulletin 334. (Full account given in this journal, May, 1915.) During the year a ceramic laboratory was established and a great many other outside and inside investigations carried out.

Metal Production in 1914 in United States.—The production of cobalt, molybdenum, nickel, tin, titanium, tungstenradium, uranium and vanadium in 1914 is described by Frank L. Hess in separate bulletin of the Mineral Resources of the United States, Part 1, No. 25. No cobalt is known to have been produced in the United States in 1914. The production of molybdenum was comparatively small, but the interest in its mining was much greater. About 400 tons of nickel was saved as a by-product in electrolytic copper refining, but the bulk of the nickel was produced electrolytically at Bayonne, N. J., as usual, from matte from Copper Cliff, Ontario. No tin was produced except a small amount from Alaska. Titanium, as usual, was produced only by the American Rutile Co., at Roseland, Va. Tungsten ore of 60 per cent WO_3 was produced to the extent of 435,000 tons. Radium, uranium, and vanadium ores were produced to the extent of 4294 short tons, carrying 87.2 tons of uranium oxide and 22.3 grams of metallic radium. This is the largest production of these ores to date. The total quantity of vanadium in the carnotite and other ores mined was apparently about 433 tons.

Another bulletin of the Mineral Resources, Part 1, No. 26, gives the production of antimony, arsenic, bismuth, selenium, and tellurium in 1914. Practically no antimony ore is known to have been smelted here in 1914, although a small amount was isolated electrolytically from the anode mud left in electrolytic lead refining. The output of white arsenic (arsenious oxide) was 4670 short tons. Bismuth was produced in small amounts, from one mine as a by-product of the smelters. Selenium was produced to the extent of 22,867 lbs., but very little tellurium is known to have been saved.

New Construction for United States Steel Corporation.—Improvements at the Gary, Ind., plant of the United States Steel Corporation to cost $25,000,000 were announced a short time ago by Chairman E. H. Gary. A first-class tube plant will be built, including ore docks, yards, blast furnaces, and all the other necessary shops, mills and auxiliary departments. This brings the total expenditures announced since the beginning of the year up to $65,000,000. The former expenditures announced included the erection of batteries of by-product coke ovens at the Youngstown plant of the Carnegie Steel Company and a bar mill plant. Work will be started this spring on the extensive by-product coke ovens at Youngstown.

Digest of Electrochemical U. S. Patents

PRIOR TO 1903

Arranged according to subject-matter and in chronological order.

Compiled by Byrnes, Townsend & Brickenstein, Patent Lawyers, National Union Building, Washington, D. C.

Aqueous Bath Apparatus

(*Concluded*)

679,050, July 23, 1901, Raoul Girouard, of Westbrook, Me., assignor to S. D. Warren & Company, of Boston, Mass.

Relates to a liquid-feed device for electrolytic cells and similar apparatus, and consists of a supply vessel which is kept filled by a ball valve, or the like, and which is provided with a restricted outlet, such as a small bore tube, feeding into a delivery device consisting of a container having an outlet in its vertical wall of greater capacity than the small bore tube. During operation, the liquid enters the container slowly and passes through the outlet in drops, separated by bubbles of air, the size of the drops and of the air-bubbles being determined by the size of the outlet tube. The drops of liquid from the outlet tube fall into the supply funnel of the electrolytic cell at a continuous rate, and provide a substantially uniform supply of liquid.

697,788, April 15, 1902, David Wesley Blair, of Perth Amboy, N. J., assignor of one-half to James C. McCoy, of Perth Amboy, N. J.

Relates to a crane for lifting anodes and cathodes out of electrolytic tanks. The crane is provided with long parallel horizontal supporting arms capable of a small longitudinal movement, and from which depend hooks capable of being turned to approach each other, or to be separated further apart. Anodes are generally supported from the sides of the tank by lugs, and when it is desired to remove a set of anodes, the hooks are separated and lowered to engage the lugs; when it is desired to remove a set of cathodes the hooks are turned toward each other, and lowered, the cathodes generally being suspended from rods which may be engaged near the center. One set of hooks on the crane thereby provides for raising both anodes and cathodes.

This concludes the patents in the class of Aqueous Bath, Apparatus, prior to 1903.

Aqueous Bath, Cathodes

61,074, Jan. 8, 1867, John L. Kendall of New York, N. Y., assignor to himself and R. H. Trested, of same place.

Relates to making dies for making imitations of straw hats from a suitable prepared fabric. The die consists of two parts, the outer of which is made by electroplating copper upon the graphited surface of the outside of a model straw hat, removing the straw, and reinforcing the copper deposit by a suitable fusible alloy. The inner, or counter-die is made by coating the copper deposit with a thin uniform layer of clay or the like, filling the clay lining with fusible metal, and after cooling, separating and cleaning. The fabric imitation is pressed between the inner and outer dies.

171,464, Dec. 21, 1875, William E. Worthen and Richard S. Gillespie of New York, N. Y.

Relates to making statuettes, etc., by first forming a core of plastic conducting material, made of powdered coke, charcoal, or plumbago, united by a waterproof binder such as asphalt. The core is then coated with plumbago as usual. The shaped and coated core is a conducting mass, and will serve as a cathode for deposition. The conductivity of the core is increased by increasing percentage of coke dust, the particles of which

have many sharp points making better contact with each other. The coated core is electroplated with copper or other metal, and is suitable for architectural or other purposes.

193,922, Aug. 7, 1877, Henry R. Cassel of New York, N. Y.

Relates to making rolls or cylinders having figured surfaces for producing imitation morocco leather, etc. A split cylindrical mold is lined with leather, etc., with its figured surface exposed. The figured surface is covered with graphite, the split molds are united and enclose a concentrically supported anode of copper. The mold and anode are suspended in a copper sulfate solution, and the surface of the leather electroplated to a suitable thickness. When completed, the mold and anode are removed, the deposited copper cylinder separated from the leather, and mounted upon a suitable mandrel for use as a roll for embossing leather, etc.

198,209, Dec. 18, 1877, Alexander E. Outerbridge, Jr., of Philadelphia, Pa.

Relates to making metallic leaf, such as gold-leaf, by electrodeposition. The deposit is effected upon an extended smooth surface of metal, or non-metal, which is provided with a conducting coating such as bronze powder. When the deposit is completed, the metal or non-metal support is removed by a suitable solvent, such as dilute nitric acid, dilute perchlorid of iron, alcohol, etc., and the gold leaf collected upon a glass sheet. It is then floated on water for washing, and again collected. It is then packed in the usual "books." The patent states that gold foil thinner than that made mechanically may be obtained in this manner.

202,969, April 30, 1878, James W. Tufts of Medford, Mass.

Relates to the making of articles by electrodeposition, and consists in forming a mold of the shape desired, by recessing a surface, electrodepositing upon the surface and recess, and after completion cutting away the metal deposited upon the surfaces which served as a support for the irregular extensions of the formed article.

276,777, May 1, 1883, Noah L. Cocheu of Brooklyn, N. Y., assignor to himself, Timothy Youle Brown of New York, and George Brown Walton of Brooklyn, N. Y., trustees.

Relates to the manufacture of rolls by electrodeposition, the rolls to be used for making imitation morocco leather, etc. The leather is cut into strips of suitable width, made acid-proof by suitable oils or varnish, wound as a helix upon a true cylinder with the irregular surface in contact with the cylinder. The leather is retained in its position by a suitable paste or cement, and is backed by a supporting cement. The cylinder is then withdrawn, the surface of the leather metallized, and placed as cathode in an electrolytic bath. The anode consists of a helix of copper having about the same surface as the cathode. After deposition, the leather is removed from the copper deposit, and the latter turned true inside and mounted upon a mandrel.

282,879, Aug. 7, 1883, Davis Garrett of Pittsburgh, Pa., assignor of one-half to Alexander Gordon of same place.

Relates to the manufacture of parabolic reflectors for use as headlights, etc. A negative is made of easily fusible metal, which is ground and polished, and upon this an electrodeposit is made without the use of graphite or other conductive coating. After a sufficient coating has been deposited the fusible metal negative is melted out and the surface of the deposited metal polished and silver-plated if desired.

290,949, Dec. 25, 1883, William Wallace of Ansonia, Conn.

Relates to the manufacture of hollow articles by electrodeposition and to the method of separating the deposit from the mold. In the making of a headlight reflector, a hole, which is temporarily closed, is made through the solid core upon which the deposit is made, and after the deposition, water under high pressure is forced through the hole and between the deposit and the surface of the solid core, thereby separating the deposit from the core.

313,805, March 10, 1885, John J. Callow of Cleveland, Ohio.

Relates to the manufacture of perforated or recessed metal goods, suitable for stencils, printing, etc. A glass plate is etched at predetermined places, to a suitable depth, the etched portions then roughened with a sand blast, the rough surfaces are then coated with graphite and electrodeposited upon, the deposition being continued until a sufficient thickness is obtained. It is then removed and smoothed, trimmed and finished.

340,460, April 20, 1886, Lewis H. Rogers of Kansas City, Mo.

Relates to the manufacture of wax forms for the production of hollow articles such as parabolic mirrors. Suitable male and female metallic molds are made, and secured to waterjackets. Wax is supplied to the space between the molds, the latter are pressed together, and steam admitted to the waterjackets to melt the wax. Pressure is then applied to compress the wax and to destroy any air bubbles that may be on the surface of the molds. Cold water is then supplied to the waterjackets to chill the wax form, after which it is removed and coated with graphite and eletcroplated.

396,911, Jan. 29, 1889, Henry F. Belcher of Irvington, N. J.

Relates to the manufacture of mosaics of glass, and refers to his prior patents for such articles. The pieces of glass are suitably secured in the openings of a metallic frame having the desired design, and a deposit of copper produced upon the frame so as to overlap the edges of the glass pieces on both sides, thereby securing them permanently in place. Different metals may be deposited at desired places, thereby producing more ornamental results.

454,381, June 16, 1891, Alexander Carl Reinfeld of Vienna, Austria-Hungary.

Relates to preparing cathode surfaces for the easy removal of a deposit. A cathode having a nickel surface, which may be solid nickel, nickel alloy, or nickel plate, is cleaned and then treated with a weak oxidizing solution, such as potassium chromate, etc., which produces a very slight film of oxide. The oxide surface may then be rubbed with a soap-like mixture to further polish it. It is then connected as cathode and immersed in the electrolyte. Deposits formed on this surface are said to be readily removed. After each deposition, the nickel surface requires reoxidation. The process may be used for the production of very thin gold-leaf, and for other uses.

480,186, Aug. 2, 1892, Francis Edward Elmore and Alexander Stanley Elmore of Leeds, assignors to Elmore's American and Canadian Patent Copper Depositing Company, Limited, of London, England.

Relates to the manufacture of tubes by electro-deposition of metal upon a mandrel, the deposit being burnished as it is formed. Te deposit adheres to the mandrel and requires mechanical treatment to loosen it. This is effected by pressing a roller against a thin deposit upon the rotating mandrel, and advancing the roller along the length of the mandrel, thereby loosening the entire deposit except at a narrow band at one end. The deposit is then continued to the desired thickness, when the narrow adhering band is cut off, and the tube removed.

485,919, Nov. 8, 1892, Francis Edward Elmore of Leeds, assignor to Elmore's American and Canadian Patent Copper Depositing Company, Ltd., of London, England.

Relates to the manufacture of tubes by electrodeposition of metal upon a mandrel. The mandrel consists of a perfectly smooth tube which may have been made by electrodeposition; the surface of the mandrel is covered with a fusible material such as paraffin, or fusible metal, which is carefully smoothed. The paraffin is coated with graphite, and electric contact made with the mandrel by removing portions of the paraffin, the graphite filling the openings. Or the paraffin may be mixed with salt and after it is applied, the salt dissolved out, leaving pores which are to be filled with graphite. The coated tube is then electroplated to the desired thickness, the fusible material thereafter melted, permitting the removal of the tube.

510,013, Dec. 5, 1893, Carl Endruweit of Berlin, Germany.

Relates to the manufacture of so-called metal paper, such as nickeled or bronzed paper. The deposit of metal for the paper is deposited upon a highly polished brass or nickel surface which has been treated with a 5 per cent solution of potassium trisulfid (K_2S_3) or the like, the solution containing a little alcohol to remove grease, etc. The cathode so treated has an effective coating permitting the easy removal of deposits. The cathode then receives a thin deposit of copper or nickel or other metal, in a neutral electrolyte, and then a deposit of the metal in an acid electrolyte to the desired thickness; it then receives a thin deposit of zinc from a zinc electrolyte. The zinc deposit is treated with a solution of ammonium hydrosulfate, mercaptan, sulfid of allyl. The sheet of paper, coated with starch paste containing one fourth of animal glue, is then pasted on the metal deposit. The foil is removed from the cathode. Coppered paper may be rubbed with a mixture of gold or silver cyanate with carbonate of potash which produces a gold or silver paper.

554,243, Feb. 11, 1896, Samuel Crump of Spokane, Wash.

Relates to a method of producing molds for paper-making machines, either of the cylinder, Fourdrinier or hand type, and consists in electrodepositing copper upon the wire screen in pre-arranged patterns, thereby closing the meshes of the wire screen, and forming open patterns in the wire mesh for the reception of the paper pulp. The open pattern is produced by covering the wire screen with wax or other resist, and electroplating upon the uncovered portions to the desired thickness. The wax resist is then removed and the screen is ready for use.

574,843, Jan. 5, 1897, William H. Winslow of Chicago, Ill.

Relates to the forming of tile-sections into a body, the tiles may consist of opaque pieces, or of glass, particularly for securing heavy vault-light prismatic tiles into a frame, by electrodeposition of metal in the spaces between the tiles and the frame. The frame is suitably supported and the prisms properly placed in the openings. Metallic strips are placed between the prisms, leaving spaces for electrodeposited metal, to serve as cathodes. If desired, the spaces betwen the prisms and metallic strips may be filled with metal filings to save some electrodeposited metal. The frame with the prims, etc., is now immersed in the electrolyte, and deposition effected, the metal filling the spaces and firmly securing the prisms. The deposited metal may extend beyond the surfaces and overlap the edges of the prisms if desired.

577,070, Feb. 16, 1897, Harry Sandham of Spokane, Wash., assignor to Samuel Crump of same place.

Relates to the production of molds for paper-making machines, and consists in coating the obverse side of the screen with a suitable resist to produce a design thereon, then to the revere side securing a piece of waxed paper which has had its wax surface metallized or made conducting by graphite. The screen and waxed paper are now immersed in the electrolyte and the meshes in the screen not closed by the resist are closed by the electrodeposit which forms a solid sheet of metal with the wire cloth. The screen is then removed, the resist washed off with a suitable solvent, and the screen with the design upon it is ready for use.

Book Reviews

The Mining Manual and Mining Year Book for 1916. By Walter R. Skinner. 957 + lxxi pages. Price 15s. net. (Post free in U. S. 17s.) London: Walter R. Skinner.

This is the thirtieth consecutive yearly issue of this work. It covers every section of the London mining market and many mines whose shares are not dealt in at present on the London Stock Exchange, including the most important companies in North and South America. The alphabetical arrangement adopted last year has been continued and should prove the handiest form for quick reference. The supplementary index which contains the names of companies which have been considered to be of not so much interest, has been separated this year from the index proper and placed at the end of the book to avoid confusion. In the dictionary of mining terms those used in Russian reports should prove helpful. The preface contains a review of mining conditions in 1915 and an appendix of several pages is added containing the latest registrations, which completes the information up to within a short time of publication (February, 1916). The high standard of the work has been maintained as heretofore.

The Journal of the Institute of Metals, Vol. XIV, edited by **G. Shaw Scott.** 289 pages, 15 illustrations. Price, 21s. net. Westminster, S. W. The Institute of Metals.

This is the second volume of 1915 and contains the proceedings of the May lecture meeting and the seventh annual autumn meeting. The papers and discussions are very interesting and deal with a variety of subjects. A lengthy paper on "Specifications for Alloys for High Speed Superheated Steam Turbine Blading," by W. B. Parker, is followed by quite an extended discussion. There is a paper on "The Constitution of Brasses Containing Small Percentages of Tin," by O. F. Hudson and R. M. Jones, which should prove of interest to brass founders. On the same subject there are two papers by D. Meneghim; one on "Structural Changes in Industrial Brasses" and one on the "Hardness of Copper-Zinc Alloys." There is a paper on a "Thermostat for Moderate and High Temperatures," by J. L. Houghton and D. Hanson; a paper on "Crystal Twinning by Direct Mechanical Strain," by C. A. Edwards; a paper on "The Physical Properties of Metals as Functions of Each Other," by A. H. Stuart; a paper on the "Copper-rich Kalchloids," by S. L. Hoyt and P. H. M. P. Brinton; a paper on the "Micro-chemistry of Corrosion in Gun Metal," by C. H. Desch and H. Hyman; a paper on the "Widmanstätten Structure in Metals and Alloys," by N. T. Belaiew, and a note on the "Detection of Internal Blow-Holes in Metal Castings by X-Ray," by C. H. Tonamy. The May Lecture of Sir J. J. Thomson, which completes this work is a valuable contribution on "The Conduction of Electricity Through Metals."